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Photogrammetric Digitizing System

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The acquisition of terrain data from aerial photography using digital photogrammetric methods gives the engineer and planner an economical alternative to conventional ground surveys. This paper describes a complete photogrammetric digitizing system developed for the Portland District Army Corps of Engineers. The hardware of the system consists of a Wild A10 first order stereoplotter interfaced to an Altec AC-74 coordinate digitizer which is interfaced to both a Hewlett Packard 9810A programmable calculator and a Digi-Data nine-track magnetic tape recorder. The software of the system consists of photogrammetric routines developed for online computation by the programmable calculator and a sophisticated FORTRAN IV

program called PHOTDIG which processes the digitized photogrammetric data from the nine-track magnetic tape at the Corps of Engineers data processing facility which contains an IBM 370 computer and a Calcomp 748 precision flatbed plotter. The processing of the digitized data by PHOTDIG produces terrain information required by engineers and planners such as state plane coordinates, elevations, cross-sections, profiles, etc. in both digital and graphical formats. The system has been in production use for over two years in the Portland District Photogrammetry Section and has significantly increased the efficiency and economy of photogrammetric data acquisition.

PHOTOGRAMMETRIC DIGITIZING SYSTEM

by

FRANK RICHARD GORSHE

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CHAPTER I

INTRODUCTION

The stereo pair of aerial photographs and the optical-mechanical stereoplotter have proved themselves to be a valuable tool to the civil engineer in the production of large scale topographical maps which are used as a basis for his design. The use of photogrammetric map compilation offers a tremendous economic advantage over the acquisition of topographical data using field surveys as the sole method.

However, traditional photogrammetric map compilation, where a topographical map at a predetermined fixed scale is directly produced by the photogrammetric technician operating the stereoplotting instrument, is being supplemented and superceded by digital photogrammetric methods, where the XYZ coordinates of terrain points are recorded into a computer readable format to permit computer processing and automatic plotting of the digitized topographical data. The advantage of using digital photogrammetric methods over conventional photogrammetric methods is the flexibility of format in presenting the data. Instead of receiving only a topographical map at a fixed scale, the engineer has a data base from which he may easily extract topographical information in a variety of digital and graphical formats.

The following chapters describe a photogrammetric digitizing system developed by the author for the purpose of processing digital photogrammetric data into various formats of topographical information useful to civil engineers and other professionals involved in project planning and design. The system consists of the interfacing of various hardware components and the development of sophisticated software to make the system functional. The basic hardware components of the system consist of a Wild A10 first order stereoeplotter, an Altec AC-74 XYZ coordinate digitizer with 9-track magnetic tape recorder, a Hewlett Packard 9810A programmable calculator with full page thermal printer, an IBM 370 high speed computer, and a Calcomp 748 precision flatbed plotter. The research of existing systems, the selection of hardware components, and the writing of the software were the major efforts in the development of the system. Of the total software development time approximately 80% was required for the FORTRAN IV routines for the offline processing and plotting by the IBM 370 and the Calcomp 748. The remainder of the software development time was required to develop routines for online processing by the Hewlett Packard 9810A programmable calculator.

The system was developed to provide topographical information in a variety of digital and graphical formats in order to eliminate much of the manual compilation which must be done when traditionally obtained photogrammetric data is to be represented in different formats. The system will provide an engineer with topographical information in the form of ground coordinates and elevations for single features, profiles, cross-sections, lineal features, and closed areas. Regardless of the processing option selected the final terrain data is always presented in both digital and graphical output. The system is unique in many aspects such as the computational methods employed in the software, the utilization of a programmable calculator for online processing, and the full utilization of automated graphics to accompany the digital output. The unique features of the system are emphasized in Chapter III where the system is described in detail.

The final chapter in conclusion describes some specific applications of the system and the benefits, economic and otherwise, derived from more than two years of production use of the system at the Portland District Corps of Engineers. The final chapter also includes some discussion of the future trends in photogrammetric systems due to the rapid changes taking place in the computer industry. In the appendices, the reader will find a user's instruction manual and source listing for the Hewlett Packard 9810A and a source listing for the IBM 370 software routines.

CHAPTER II

DISCUSSION OF THE PROBLEM

The value of vertical aerial photography to a civil engineering organization cannot be surpassed in terms of being an economical source of a nearly infinite amount of ground information. Existing maps are usually too small of a scale to be useful to the engineer and are often out of date. Field surveys and field reconnaissance are very expensive, and are often not economically justified until the later stages of a project when specific locations are being considered.

According to Whitmore (1) the first engineering application of aerial photography was in 1858 by Aime Laussedat a colonel in the French Army Engineer Corps. Colonel Laussedat prepared some maps using photography taken from an unmanned balloon. However in 1860, Colonel Laussedat abandoned the use of a balloon because of problems of obtaining the required coverage from one balloon station. He switched to the use of ground photography taken with a phototheodolite, a combination of a surveying transit and a camera. Colonel Laussedat prepared a map of Paris using his photogrammetric methods which compared favorably with maps prepared later by conventional field surveys.

The first significant engineering application of aerial photography in the United States was the complete mapping of the Tennessee River basin in 1930 using photogrammetric methods credited to Whitmore (1). This was a joint project between the U.S. Geological Survey, which had just acquired its first stereoplotters, and the Tennessee Valley Authority.

The advancement of computer technology has led to the transition from purely analog or instrumental photogrammetric methods to digital or analytical methods which allow for acquiring topographical information from the aerial photograph in a variety of formats instead of being limited to only the preparation of a topographical map at a fixed scale and contour interval. According to Doyle (2), the missile program of the 1950's required advanced photogrammetric methods for precise tracking which could not be satisfied by conventional analog methods. It appears that the space program, in conjunction with a rapidly advancing computer technology during the same time period, was the primary stimulus for the development and application of digital photogrammetric methods.

Since that time digital photogrammetric methods have gradually been accepted and applied by civil engineering organizations. According to Waggoner (3) in 1964, the Walla Walla District of the Corps of Engineers was successfully using digital photogrammetric methods to take engineering cross-sections to determine contract pay quantities. Their system consisted of a Wild A7 first order stereoplotter interfaced to a typewriter and an IBM card punch machine using a Wild EK-5 control console (digitizer). Given the rugged and steep terrain of their Columbia and Snake River reservoir projects, photogrammetric methods were an ideal substitute for conventional field surveyed cross-sections. At first some of the private construction firms under contract by the Walla Walla District were skeptical of the validity of contract payments based upon photogrammetric methods. In fact the first field checks made by the contractors did not agree with the photogrammetric quantities. However, when the precision of field surveys used to check the photogrammetric cross-sections was increased beyond what is normally utilized for cross-section surveys the accuracy of the photogrammetric cross-sections was confirmed to be more than adequate. According to Waggoner (4), their experience using photogrammetric surveys for the relocation of roads and railroads at John Day Dam on the Columbia River and Ice Harbor Dam on the Snake River indicated a cost savings of at least fifty percent in comparison with conventional field cross-sections surveys. However, to obtain accuracies comparable with the photogrammetric surveys would have required field survey methods costing around forty times the photogrammetric surveys because of the steepness of the terrain. Also included in Waggoner (4) are copies of various letters from the R. A. Heintz Construction Company expressing their enthusiasm for photogrammetric quantity surveys after having performed extensive field checks using conventional surveys.

The Portland District Corps of Engineers has utilized aerial photography since the 1930's in conjunction with the planning and design of civil engineering projects. However, except until recently the Portland District Photogrammetry Section has not become involved in digital photogrammetry. Until 1974 the Portland District was limited to the production of conventional contour maps using third order Balplex stereoplotters. Any photogrammetric projects requiring digital methods such as engineering cross-sections had to be performed by the Walla Walla District or Seattle District of the Corps of Engineers. This created problems of scheduling due to the Portland District's priorities being secondary to those of another district. In 1974 the Portland District obtained a Wild stereoplotter which was declared surplus by the Walla Walla District. Since the Wild stereoplotter was of significantly higher order than the existing Balplex stereoplotters, it was decided to modify the Wild stereoplotter and acquire the components to give it a digital capability. Basically the problem consisted of selecting the appropriate hardware components and finding or developing appropriate software for processing the digitized data.

The primary hardware requirement of the proposed digitizing system was the digitizing console which is often referred to as a digitizer. The digitizer is the heart of the system in that it provides the function of counting and displaying the pulses generated from the three rotary encoders which would be mounted on the X, Y, and Z axes of the Wild stereoplotter. The three digital counters of the digitizer provide a real time display of the actual coordinate location of index mark viewed by the stereoplotter operator. The digitizer also contains the interfacing electronics for peripherals which are to receive the displayed coordinate information. The peripheral could be a typewriter, calculator, card punch machine, terminal or a combination of these devices. One option was to have a digitizer built by a local electronics engineer. The digitizer used in a photogrammetric system described by Wood (5) was designed and manufactured locally. However, the price was not competitive with other available digitizers which were manufactured in bulk as a standard production item of the firm. The selected digitizer was an Altec Model AC-74 which was considerably less expensive than any other manufacturer's equipment, yet obtained good references for dependability from the U.S. Geological Survey which had purchased many Altec digitizers. The Altec firm was also very flexible in terms of being able to interface their digitizers to a variety of peripherals for a reasonable price. Some of the more established digitizer manufacturing firms were reluctant to provide interfaces to nonstandard peripherals such as programmable calculators.

The primary peripheral of the digitizing console was to be some kind of recording device which provided an output which could be read by a regular computer system. The Portland District already was using an IBM 370 system which was capable of generating a plot tape to drive a Calcomp Model 748 precision flatbed plotter. At first an IBM card punch, which is the standard recording device in most digitizing systems, was considered for selection as the recording device. However, the Data Processing Office of the Portland District recommended the use of a nine track magnetic tape recording system instead of a card punch machine. The benefits of the magnetic tape system were speed of recording, quietness of operation, compactness of the recording unit, and lower acquisition costs. The main disadvantage was that the data recorded on magnetic tape could not be immediately read by the photogrammetric technician. Because of the advantages stated above it was decided that a nine-track tape recorder would be interfaced to the digitizing console. A Digi-Data Model 1339-800 nine-track write-only tape recorder which was available from the Altec Corporation as a standard interface was selected as the recording device of the proposed digitizing system.

The secondary hardware requirement of the system was to have some low level processing power online in the form of a programmable calculator. One of the first documented uses of a programmable calculator for a photogrammetric digitizing system was done in the Department of Civil Engineering at the University of New Brunswick by Dorrer (6). In this system a Wang Model 700A was interfaced to a Wild A10 stereoplotter to provide online data processing capability. However, unlike the proposed system of the Portland District, this system did not have the option of going to a large computer system when the processing requirements could not be met by the programmable calculator. However in a later system by Dorrer (7), a Wild stereoplotter was interfaced to a Data General Nova-800 16 Kilobyte minicomputer and a ASR33 teletype terminal with a high speed paper tape reader. The ASR33 terminal served as a communication link between the photogrammetric technician and the Nova-800 minicomputer. The Nova-800 minicomputer was planned to be interfaced with an IBM 370 system eventually to provide higher level processing and storage capabilities. The selected programmable calculator for the Portland District digitizing system was a Hewlett Packard 9810A. The decision was based on the availability of the calculator and good references received on its dependability and performance from other users including Professor Dorrer who at that time was using the Hewlett Packard 9810A instead of the Wang 700A calculator as used in his system previously described.

After selection of hardware components, there still remained the problem of software acquisition for processing the data recorded on the nine-track magnetic tape recorder and the data transferred directly to the Hewlett Packard 9810A programmable calculator. The first consideration was to try and locate existing software in order to avoid expensive and time consuming inhouse software development. The Walla Walla District of the Corps of Engineers could not furnish any existing software to meet our processing requirements because their system was limited primarily to producing cross-section data directly from the IBM card punch machine interfaced to their digitizing console. Another possible source was the Texas Highway Department which was developing an automated mapping system as described by Howell (8). This system had some similarities with the software objectives of the Portland District, but was still in the development stage. Also the Texas Highway system was limited at that time to being able to digitize two axes of the XYZ coordinate system of the stereoplotter which was not compatible with the Portland District's system objectives. Other agencies were consulted, but usually the existing software was limited to specialized tasks and formats required by that agency or the hardware configuration of the system was too different from that proposed by the Portland District to permit easy conversion. It was then decided to develop inhouse the FORTRAN software for processing the digitized data on magnetic tape and the programmable calculator software for data transferred directly to the online Hewlett Packard 9810A. The software development was performed by the author of this paper who at that time was Chief of the Photogrammetry Section for the Portland District Corps of Engineers. The following chapter will describe in detail the hardware, software, and capabilities of the system developed.

CHAPTER III

DESCRIPTION OF THE SYSTEM DEVELOPED

SYSTEM CONFIGURATION

As mentioned in the introduction, the basic hardware components of the system consist of a Wild A10 first order stereoplotter, an Altec AC-74 XYZ coordinate digitizer with 9-track magnetic tape recorder, a Hewlett Packard 9810A programmable calculator with full page thermal printer, an IBM 370 high speed computer, and a Calcomp 748 precision flatbed plotter. A schematic of the system components and operation is shown in Figure 1. The stereoplotter, digitizer, and programmable calculator are physically interfaced and located together as shown in Figure 2. The 9-track magnetic tape containing raw digitized data is hand carried to a separate data processing facility where a Harris mini-computer system functions as a high speed terminal to the IBM 370 which is located in another office building in downtown Portland. The FORTRAN IV program, which was developed by the author specifically for this system, processes the data on the 9-track magnetic tape and generates a printer listing and magnetic plotter tape at the data processing facility where the raw data was originally submitted. The printer listing contains the digital topographical data in the final format as required by the engineer. The magnetic plotter tape is used to drive the Calcomp 748 to produce a plan view graphical representation of the same digital topographical data at any desired scale. A photograph of the Calcomp

PORTLAND DISTRICT PHOTOGRAMMETRIC DIGITIZING SYSTEM (PHOTDIG)

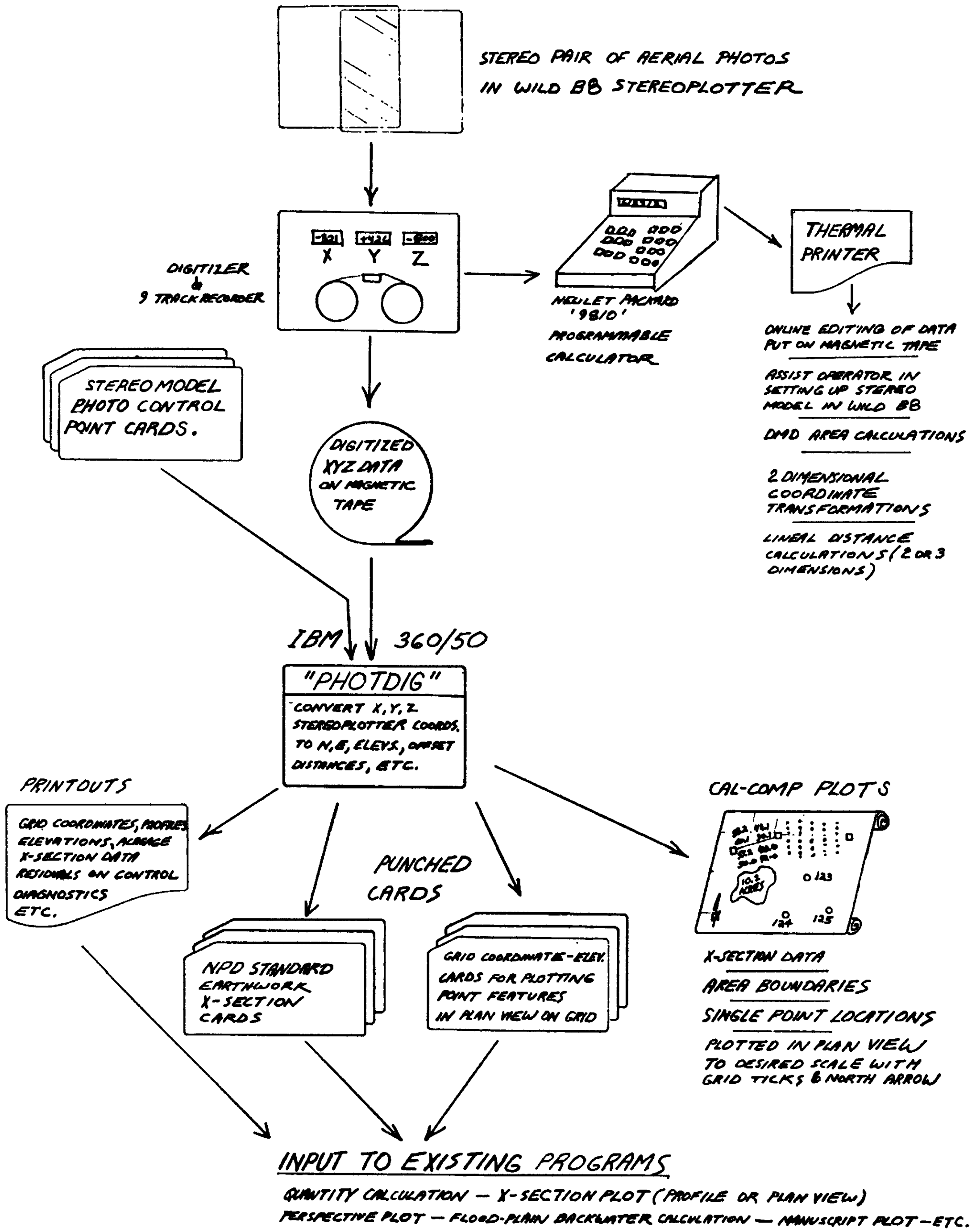

Figure 1. System schematic

Figure 2. Stereoplotter and digitizing equipment

plotter and controller unit is shown in Figure 3.

The basic or central component of the system is the Wild A10 stereoplotter as shown in Figure 2 being operated by a photogrammetric technician. The stereoplotter is a precision optical mechanical instrument which accepts a stereo pair of 9" x 9" aerial photographs contact printed on glass plates from the aerial negative film. A typical stereo pair of aerial photographs (reduced to half size) is shown in Figure 4. These aerial photographs are the starting product used to produce the Calcomp plot and the computer listings shown later in this chapter. The circled areas on the stereo pair of aerial photographs are where the field surveyed photo identifiable control points are located. The stereoplotter operator sees a three dimensional view of the terrain by looking through a binocular optical viewing system which channels the imagery of the left aerial photograph to the left eye and the imagery of the right aerial photograph to the right eye. The terrain view of the stereoplotter operator is similar to that of a person in the aircraft which took the aerial photography except that the stereoplotter operator sees a more exaggerated view of the terrain relief. The operator also sees a floating black dot which can be moved horizontally in independent X or Y motions by the use of handwheels or vertically in a Z motion by the use of a wheel which he turns with his foot. The X and Y handwheels are mechanically interfaced to a carriage holding a pencil on a large horizontal plotting table as shown in the lower right corner of Figure 2. The Z motion is mechanically interfaced to a Z counter which permits the operator to read the elevation of the floating dot when it is set on the apparent ground surface of the stereo model. To map a specific contour

Figure 3. Calcomp plotter with controller unit in background

Figure 4. Stereo pair of aerial photographs

the operator would set the floating dot at the desired elevation, and would then move the dot horizontally along the surface of the terrain using the X and Y handwheels. Since the X and Y handwheels are interfaced to X and Y motions of the pencil carriage one can map the contour with the floating dot. Using similar procedures the operator can map the location or obtain the elevation of planimetric features such as houses, highways, streams, lakes, etc. The above is an explanation of how the stereoplotter is utilized in a traditional or non-digital mode. If the reader desires a more in-depth presentation of basic photogrammetry he should consult Wolf (9).

To provide a digital capability to the Wild A10 stereoplotter each axis of the stereo model coordinate system (XYZ) is equipped with a Dynamics Research Corporation Model 77 rotary encoder. The rotary encoders transmit electrical impulses to the Altec Model AC-74 digitizer shown in Figure 5. The electronics of the digitizer count the pulses and display the counts independently on the X, Y, and Z display counters on the front of the digitizer so they may be easily read by the stereoplotter operator. The digitizer gives the operator a real time display of the coordinate location of the floating dot seen within the apparent stereo model. This orthogonal XYZ coordinate system is a stereoplotter or machine coordinate system in terms of units and orientation. The unit represented by a single count of the digitizer in any axis is one micron. The orientation of the stereoplotter coordinate system is fixed by the construction of the machine. However, of ultimate concern to the engineer is topographical information in terms of ground coordinates. Ground coordinates consisting of easting and northing values are expressed

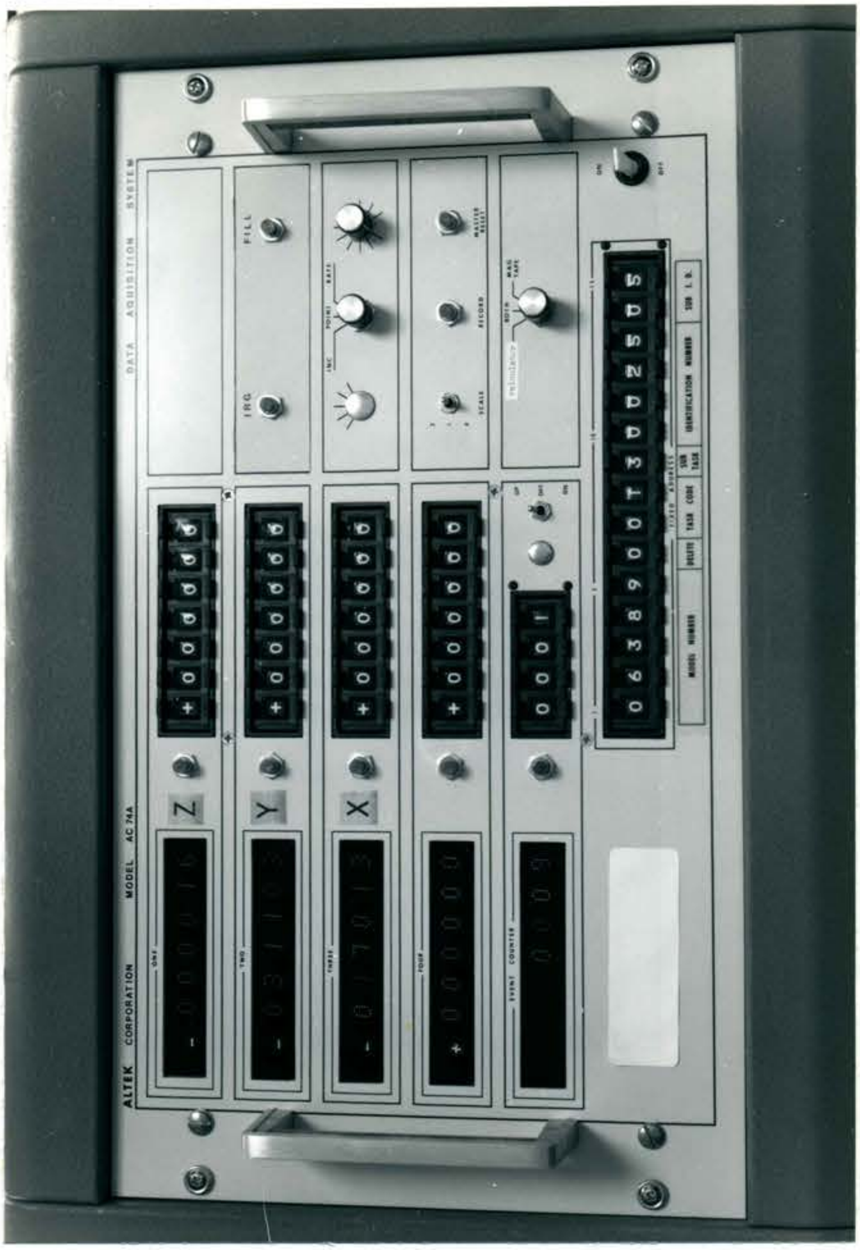

Figure 5. Digitizing console

in feet and are usually related to the State Plane Coordinate system. The third axis of the ground coordinate system is elevation, which is normally expressed in feet above Mean Sea Level or some other vertical datum. The Z coordinate axis of the stereoplotter is usually oriented parallel to the elevation axis of the ground coordinate system or at least within a few degrees of being parallel. The X and Y plane of the stereoplotter system will be closely parallel to the easting and northing ground system, but the individual axis forming the horizontal planes are almost always rotated. The only time that the X axis of the stereoplotter would be even closely parallel to the easting axis of the ground coordinate system would be if the direction of the flightlines of the aerial photography were parallel to the east direction of the ground coordinate system. Even if this were intentionally attempted it would still not produce the degree of parallelism required for mathematical conversion between coordinate systems without introducing rotation factors. The mathematics of conversion from the XYZ machine coordinate system to the easting, northing, and elevation coordinate system will be discussed in detail later in this chapter.

In addition to providing a real time XYZ display of the stereoplotter coordinate system, the digitizer is equipped with 15 digital switches called the Fixed Address on the console which may be set to any value desired by the stereoplotter operator. As shown in Figure 5, these 15 switches have been subdivided into different named groups by a label under the switches. For example, the first five digits are called the Model Number, the next digit a Delete Code, the next two digits a Task Code, etc. These 15 digits as well as the XYZ coordinates are transmitted to the 9-track magnetic tape and the calculator when the stereoplotter operator presses a foot switch to record the current location of the black dot in the stereomodel. The use of the 15 digital switches allows the stereoplotter operator to code the coordinate data transmitted to the magnetic tape or the calculator. The various codes or named groups into which the 15 digits have been divided are read as individual variables by the software of the Hewlett Packard programmable calculator or the FORTRAN IV program of the IBM 370. The codes serve as either identification for the digitized point or as software flags to determine that the appropriate processing option of the computer program is used as selected by the stereoplotter operator. Also present on the face of the digitizing console is an event counter. The event counter increments each time the stereoplotter operator activates the foot switch to record a point. The event counter may be reset to one at the option of the stereoplotter operator. Like the displayed XYZ coordinates and the 15 digits of fixed data, the event counter is also transmitted to the 9-track magnetic tape recorder and the Hewlett Packard programmable calculator. The event counter serves as a means of identifying each recorded point and also serves as a flag to assist in the control of the calculator and IBM 370 software processing options. The event counter also assists the stereoplotter operator by letting him know what point he has just finished recording in situations where his attention has been diverted from the task at hand. The back of the digitizer console contains a patch board panel which allows for programming the format and the sequence of the data transmitted to the magnetic tape recorder and the programmable calculator. For example, in this system the patch board panel has been programmed for the following sequence of data to be transmitted from the digitizer for a total of 40 digits: fixed data, event counter, X, Y, and Z coordinates. The calculator receives these 40 digits immediately. However, the tape recorder is set for an eighty character record for consistancy with the eighty characters of a standard IBM card. Consequently an 80 character record consisting of data for two points is transmitted to the magnetic tape recorder every other time the stereoplotter operator activates the foot switch to record a point. The sequence and format of the digitized data for one magnetic tape record is shown in Figure 6.

The digitizer has three interface modes as selected by a switch on the front face of the digitizer. In the first mode, the digitizer transmits only to the calculator. This mode is used when the calculator is used independently to provide processing routines which do not require the high level processing power of the IBM 370. In the second mode, the digitizer transmits simultaneously to the calculator and magnetic tape recorder. This mode is used when the calculator with the thermal printer functions as a formatting and listing device for the data being recorded on magnetic tape. In the third mode, the digitizer transmits only to the tape recorder. This mode would only be used in the case where the calculator or thermal printer is not working and the operator would have to record data on magnetic tape without the benefit of a listing.

The magnetic tape recorder is a Digi-Data Model 1339-800 9-track write-only tape recorder. It is mounted below the programmable calculator in the digitizing console as shown in Figure 2. The density of the data recorded on tape is 800 BPI (Bytes Per Inch). In this application,

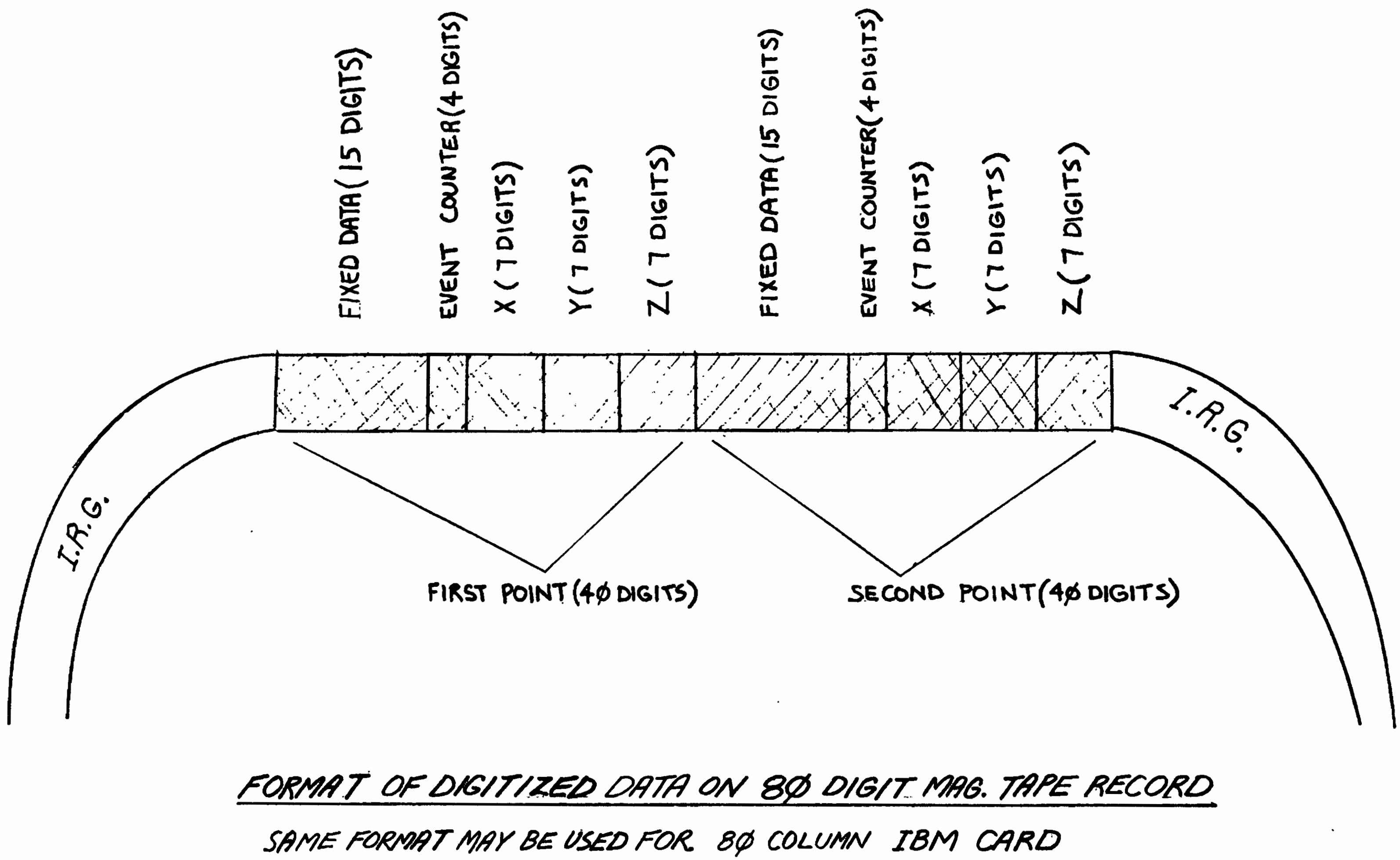

Figure 6. Record format of digitized data

each 80 digit record would require a tenth of an inch of tape plus the space required for the I.R.G. (Inter Record Gap). One reel of magnetic tape can hold the information which would require a dozen or more large boxes of conventional IBM cards. In certain photogrammetric digitizing applications where large numbers of points are recorded, the use of magnetic tape has a definite advantage over the use of IBM cards in terms of compactness of data. Traditionally, most photogrammetric digitizing systems for civilian applications have incorporated IBM card punch machines rather than magnetic tape recorders. One of the main objections to using magnetic tape has been the photogrammetrists inability to directly read the recorded data on tape or to easily edit the data. However, in the production use of this system, there have not been any major problems related to the above mentioned objections. This is probably due to the various listing and editing capabilities incorporated into the system which will be discussed in detail later. Also the photogrammetric technicians using this system are relatively young and inexperienced in using photogrammetric digitizing systems, and consequently are probably more open to the use of different methods. In the event that recording errors are too severe to be corrected using the editing capabilities of the system the photogrammetric technician can easily convert the data to IBM cards and then edit the data. Either magnetic tape or a card deck may be used as input to the FORTRAN program, since both forms of data incorporate a record length of 80 characters. Other advantages of the magnetic tape recorder over the card punch are lower cost of the recording unit, lower overall cost of the recording medium, compactness of the recording unit, compactness of the recording medium, and quietness of the recording unit.

The digitizing console is also interfaced to a Hewlett Packard 9810A programmable calculator. The programmable calculator is equipped with options providing for 111 storage registers and 2036 program steps. A storage register is eight bytes of information and a program step is one byte. Not counting the math function ROM (Read Only Memory) we have a mini processing system with the equivalent of around 2,800 bytes of data and program storage capability. Unlike larger systems which can be programmed in higher level industry standard languages such as BASIC and FORTRAN, the Hewlett Packard 9810A programs in its own keyboard language unique to this particular model. Because the language is lower level and approaches the directness of a machine language, the programs are usually fast and efficient. For a more detailed description of the calculator and how it programs the reader should consult Hewlett Packard (10).

The Hewlett Packard 9810A programmable calculator is interfaced to a Hewlett Packard Model 9866A full page thermal printer. This device will print 80 characters per line at a rate up to 240 lines per minute. The thermal printer is somewhat more expensive than a conventional typewriter interface, but is well worth the cost in terms of speed and reliability. The speed of the magnetic tape recorder and the thermal printer make it possible to digitize points in a rate mode in addition to just the conventional point mode. When the rate mode is selected by activating a switch on the digitizing console, points will be recorded at a continuous rate as long as the foot switch is pressed down by the photogrammetric technician. The rate in terms of points per second is selected by a dial on the digitizing console. The rate mode is useful when digitizing the coordinates of a continuous lineal feature such as the edge of a road or the shore of a lake. In conventional systems using card punch machines and typewriters it is not possible to record in a rate mode because of the slowness of these devices. A photograph of the calculator and thermal printer is shown in Figure 7.

The digitized data on the 9-track magnetic tape is processed by the IBM 370/155 computer system of the North Pacific Division of the Army Corps of Engineers. It is a conventional large data processing facility with high speed printer, card reader, card punch, read/write magnetic tape drives, and large capacity disc storage systems. The FORTRAN IV program which processes the digitized data requires 90 kilolytes of computer memory and a modest amount of online sequential storage. It requires a 9-track read/write magnetic tape machine to read the digitized data and also produce the magnetic tape which will drive the flatbed plotter offline. For the final output of the program a 130 character printer is required. The FORTRAN program could easily be run on other data processing systems. If the data processing system did not have a flatbed plotter, the program could be modified to exclude the plot producing statements. The printer listing by itself would give the engineer the coordinate, elevation, and other topographical information which he would need for design or planning purposes. The plot is a very helpful supplement to the printer listing, but is not an absolute requirement.

The plotting is done by a Calcomp model 748 high speed flatbed plotter. The magnetic tape produced by the FORTRAN program, which processed the raw digitized data, is mounted on a Calcomp model 925 con-

Figure 7. Programmable calculator being operated by photogrammetric technician. Thermal printer on top of digitizing console is interfaced to the calculator to provide a hard copy of calculator output

troller unit which in turn drives the Calcomp plotter. The controller unit and the flatbed plotter are shown in Figure 3. The model 748 has a plotting surface of 48 x 82 inches which is sufficient for most engineering and cartographic applications. The plotting head has four separate pens which can be independently called to write by statements in the FORTRAN program. The plotting head can move at velocities up to 42 inches per second. Ball point pens, liquid ink pens, or a scribing tool can be mounted on the plotting head. Plotting can be done on paper, mylar film, or cartographic scribe coat material. The surface of the plotting bed contains a vacuum system for holding the drawing material flat against the plotting surface. The absolute accuracy of the plotting system is very high. The actual plotted location of a point should not deviate from its specified coordinate location by more than several thousandths of an inch. A sample plot produced by the system is shown in Figure 8. The plotted data was digitized from the stereo pair of aerial photographs shown in Figure 4.

ONLINE PROCESSING WITH THE HEWLETT PACKARD 9810A

In this system the online Hewlett Packard 9810A serves basically three different functions. It will assist the photogrammetric technician in performing the preliminary adjustment or "setting up" of the stereomodel in the stereoplotter. It will serve as a formatting and listing device when digitizing data to the 9-track magnetic tape recorder. It will also function as a stand alone processing device when the nature of the application does not require the high level processing of the FORTRAN program and the IBM 370.

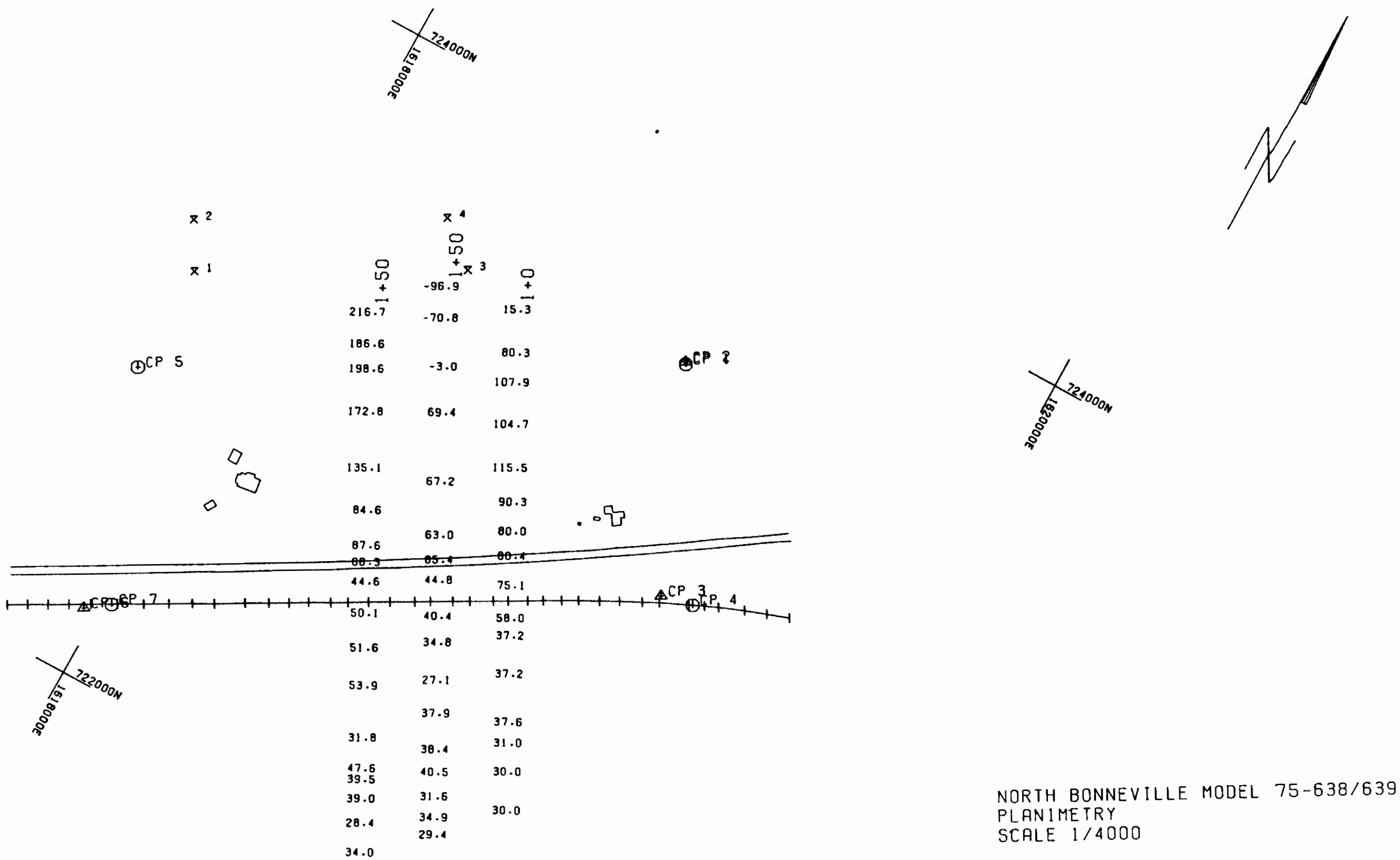

Figure 8. Sample Calcomp plot produced by PHOTDIG

The Hewlett Packard 9810A has been programmed for nine different photogrammetric routines which can all be loaded into machine memory with the insertion of a magnetic card. Each routine can be accessed independently as a separate program by pressing the appropriate keys on the calculator keyboard. The actual use of the routines is described in detail in Appendix A which contains a copy of the user's instructions for the photogrammetric routines. The words spelled in all capitals represent actual keys of the programmable calculator.

One of the primary applications of the online Hewlett Packard 9810A is to perform computations which will assist the stereoplotter operator in "setting up" the stereomodel. The setting up procedure consists of adjusting the two aerial photographs in the stereoplotter for relative orientation and absolute orientation. Relative orientation is the process of adjustment of the stereoplotter in which the photogrammetric technician attempts to duplicate the angular or rotational orientation of one photograph with respect to another. By doing this the orientation of the original exposure stations of the aerial camera is duplicated, so that the light rays from all common image points on the two aerial photographs intersect, thus allowing the stereoplotter operator to view a parallax free stereomodel. The second and the more time consuming part of the setting up procedure is called absolute orientation. This consists of scaling and leveling. Scaling is the adjustment of the distance between the aerial photographs in the stereoplotter so that the exact desired scale is produced on the plotting table when the map is to be compiled in a conventional manner. The operator knows that he has obtained the correct scale setting when he can move the dot in the stereoplotter optics to various photo image points of known ground coordinates and the pencil or pointer on the plotting table will move to the plotted location of the same horizontal control points on the final map sheet. At least two horizontal control points are required to establish a known scale. Leveling is the adjustment of the stereoplotter to produce elevation readings, using the dot in the stereoplotter optics, consistent with the ground surveyed elevations of at least three photo identifiable points. Three vertical points are required to level the stereomodel in a similar manner that three known points are required in analytical geometry to define a plane in space. Usually there are at least three known horizontal control points and four vertical control points to permit a check on the validity of the location and correctness of the ground surveyed coordinates and elevations. The setting up procedure can be tedious and time consuming because of its iterative nature. Changing the level of the model will change the scale and distort the relative orientation, therefore requiring that the operator make many iterations of relative orientation, level adjustment, and scale adjustment until the corrections become small enough to be ignored. A skilled and experienced operator can do the complete setting up process in an hour or less. A less skilled and less experienced operator can take as long as eight hours to perform relative and absolute orientation especially if the stereomodel consists of difficult terrain or has a bad control point.

Routines 1 and 2 as described in Appendix A will assist the operator in performing the absolute orientation phase (scaling and leveling) of the setting up procedure. Routine 1 allows for the input of up to 20 control points consisting of ground coordinates and elevations. Routine 1 is used in conjunction with most of the other routines, because ground control points are always needed as a basis of computation to convert machine or stereoplotter coordinates into some form of final data in ground units of measurement such as distances, coordinates, elevations, slopes, etc. In the process of inputting values for the control points using routine 1, a point number is assigned to each control point. Therefore in using other routines which require stored control point values the point is referenced by the assigned point number. Once the operator has input the values of the photo control points into machine memory using routine 1, he can perform the scaling and leveling procedure using routine 2. The operator will select two photo identifiable control points which he considers most suitable for scaling and leveling. He will then input the point numbers of each control point using the calculator keyboard. Next he will move the dot in the stereoplotter optics to the photo location of the first ground control point. He will then press the foot switch which will activate the digitizing console to send the machine coordinates of the first control point to the programmable calculator. The stereoplotter operator will then repeat the same procedure for the second control point. The machine coordinates of the second control point will be transmitted to the Hewlett Packard 9810A. After receiving the machine coordinates of the second control point, the programmable calculator will have the ground and the machine coordinates for each control point and can then compute the adjustments required by the stereoplotter to arrive at a level and scaled stereomodel. The new base setting in centimeters is computed and listed by the thermal printer. The new base setting is set in the stereoplotter by the photogrammetric technician by turning an adjusting knob which varies the principal distance between the perspective centers of the aerial photos. The new base setting should produce the desired stereomodel scale or at least be very close to it. The corrections in Phi and Omega (tip and tilt) in units of grads are also computed and listed by the thermal printer. The stereoplotter operator changes the tip and tilt of the stereomodel the computed amount by turning a knob for each of the two angular rotations. Once the computed corrections have been set in the stereoplotter, the photogrammetric technician will check the various control points of the stereomodel for having the proper scale and for being level. Usually the stereomodel is not perfectly level the first time the corrections are computed and set in the stereoplotter. In this case the operator selects another two control points, and repeats the procedure of digitizing the two points so that new corrections can be computed by the calculator. Without the assistance of the programmable calculator the operator must make educated guesses of what magnitude of changes to make to the base, tip, and tilt settings of the stereoplotter. This is a very tedious and time consuming process, especially for the relatively inexperienced operator. Since most of the Portland District Corps of Engineer's photogrammetric technicians are relatively inexperienced, the use of the programmable calculator has resulted in significantly increased efficiency in the setting up procedure of photogrammetric mapping.

By selecting routine F of the photogrammetric routines for the Hewlett Packard 9810A, the thermal printer will produce a neatly formatted listing of the raw digitized data which is being recorded on the 9-track magnetic tape recorder. This gives the operator an immediate record of the data which is being recorded to facilitate the editing process. All of the fixed and variable data as seen on the face of the digitizer console such as Model Number, Delete Code, Task Code, Event

Counter, Coordinates, etc. are listed in separated columns with appropriate headings. The programmable capability of the calculator allows for formatting features such as the skipping of several lines and the printing of new column headings when the Event Counter is reset to one, the Task Code is changed, or more than 30 points have been recorded. The use of the programmable calculator results in an easily read listing with automated formatting capabilities which minimize the amount of clerical work required by the photogrammetric technician.

Routines 1 and 2, which assist in the performance of scaling and leveling, and routine F which produces the formatted listing of raw digitized data are the most frequently utilized of the calculator routines. Routines 3 thru 8 provide some additional capabilities such as slope calculation, grid coordinate and elevation computation, and various other support routines which are used in specific applications which occur less frequently. For a detailed description of each routine the reader should consult the user's instructions in Appendix A. Appendix B contains a listing of the actual program steps for all of the nine photogrammetric routines.

OFFLINE PROCESSING WITH THE IBM 370

The major effort in the production of the system was the development of a FORTRAN IV program entitled "Reduction of Photogrammetrically Digitized Three-Dimensional Data" or for ease of reference "PHOTDIG". The function of PHOTDIG is to process the raw digitized photogrammetric data on 9-track magnetic tape and produce an output in digital and graphical form in various formats of ground terrain information useful to engineers and planners such as state plane coordinates, elevations, acreages, profiles, cross-sections, etc. The program operation is divided in five different tasks which may be selected by changing the Task Code on the face of the digitizing console. A FORTRAN listing of the program is contained in Exhibit C.

One of the unique features of PHOTDIG is that every digitized point is represented in graphical form in addition to the digital format on the printer listing. A plan view plot of the digitized data is furnished at any horizontal scale requested by the user. The stereoplotter operator can control the format of the final plot with a wide range of plotting options by setting the appropriate codes in the fixed data switches of the digitizing console. A sample plot representing some data from each of the five tasks is shown in Figure 8. For a more detailed description of all the program options available and their execution the reader should refer to Gorshe (11).

Task 1 (Control Points) is the primary task of the program and involves the most sophisticated mathematics. Task 1 is the only task which must be executed at the onset of digitizing data from any stereomodel, because it establishes the parameters of coordinate transformation from the XYZ stereoplotter machine coordinate system, to the easting, northing, and elevation ground coordinate system. Once these parameters have been established the remaining four tasks can be executed in any order and repeated as many times as desired. Because the coordinate transformation is three-dimensional, the stereomodel does not have to be manually leveled in the stereoplotter in many applications. Therefore the stereoplotter operator need only establish a good relative orientation during the setting up procedure. This is one of the features of PHOTDIG which makes it unique compared to conventional digitizing software which usually utilize a two-dimensional coordinate transformation because of the simpler mathematics involved. Although the two-dimensional coordinate transformation is much easier to program, it requires more production labor in the long run, because the stereoplotter operator must complete the entire setting up procedure, including scaling and leveling, before he can begin to digitize photogrammetric data. Another unique feature of PHOTDIG is the use of a least squares solution for the parameters of coordinate transformation. Although only two horizontal and three vertical control points are required for a unique solution, PHOTDIG will permit a maximum of twenty control points to be utilized in the solution. Not only does this permit a stronger solution of the transformation parameters, but it also permits the computation of residuals for each control point used. The residuals give the photogrammetrist an indication of the precision of the solution and also facilitate the detection of gross errors. The precision of the solution is a good indication of the precision of the final data obtained, because the transformation parameters computed in task 1 will be used to convert machine coordinates to ground coordinates for every point digitized using the remaining four tasks.

The mathematics for the least squares solution of the parameters of the three-dimensional conformal coordinate transformation are found in Appendix B-7 of Wolf (9). The basic problem consists of solving for the seven independent coordinate transformation parameters which will permit the conversion of stereoplotter XYZ coordinates in microns into ground or state plane coordinates consisting of easting, northing, and elevation values in feet. The seven parameters consist of a scale factor, three translation factors (one for each axis), and three rotation angles (a rotation about each axis). Knowing these seven parameters define the relationship between two three-dimensional coordinate systems and will permit the direct conversion of coordinates from one system to another. If the horizontal coordinates of two points and the vertical coordinates of three points are known in both coordinate systems, then the seven orientation parameters can be solved for directly. This seems reasonable since knowing two horizontal points and three vertical points produces a total of seven known coordinate values common to both systems, which in turn allows for the unique solution of the seven orientation parameters. Each additional known coordinate of a point common to both systems would therefore contribute to the strength of the solution by adding a degree of freedom to the least squares solution.

To perform task 1, the stereoplotter operator digitizes the XYZ coordinates of each known control point. A maximum of twenty control points can be used in the solution of the parameters. Typically, four to six control points are available. The stereoplotter XYZ coordinates of the control points are recorded on the magnetic tape. When the magnetic tape is submitted for processing by PHOTDIG, a deck of IBM cards is also submitted. In addition to containing job control and header information cards, the deck contains a control point card for each control point which was digitized. The control point card contains the field surveyed or ground values of the easting, northing, and elevation coordinates of the control point. If only the vertical or horizontal values of the point are known, then only the known values need be included on the control point card. By reading the XYZ stereoplotter coordinates from the magnetic tape and the easting, northing, and elevation values from the control point cards, PHOTDIG will have values from both coordinate systems which will be used to solve for the seven parameters of coordinate transformation. The actual solution for the transformation parameters is not a direct computation because of the non linear relationship between the coordinates and the parameters. The observation equations must be linearized using Taylor's theorem as shown in detail in Appendix B-7 of Wolf (9). After being linearized the observation equations permit the solution of corrections to the transformation parameters, rather than the parameters themselves. This requires that PHOTDIG compute initial approximations of the parameters which are reasonably close to the actual values so that the computed corrections to the parameters become smaller with each iteration and finally become so small that the parameters can be considered to be final values. Because of the redundancy of the control point data there are usually more observation equations than unknowns, therefore the least squares technique of normalization must be applied to the observation equations to produce a final set of equations equal in number to the unknowns. Given the same number of equations as unknowns, the corrections to the parameters are solved directly using Gaussian elimination. This solution occurs once for every iteration required. A printer listing showing the results of executing task 1 for the solution of the transformation parameters is shown in Figure 9.

Once task 1 has been completed by the stereoplotter operator, he may then execute any of the remaining four tasks in any order. All of these four tasks require the conversion from the stereomodel coordinates

```
PHOTOGRAMMETRIC DIGITIZING PROGRAM - PORTLAND DISTRICT CORPS OF ENGINEERS PHOTOGRAMMETRY SECTION
***********************************************************************************************
         NORTH BONNEVILLE MODEL 75-638/639        PLANIMETRY

         SCALE = 1/   4000        NORTH ANGLE =  330.0DEGS


                              CONTROL POINTS
                              **************
                              MODEL NUMBER  6398

SEQUENCE NO.  X-MODEL  Y-MODEL  Z-MODEL  X-GRID(EAST)  Y-GRID(NORTH)  Z-GRID(ELEV.)  X-RESIDUAL  Y-RESIDUAL  Z-RESIDUAL  POINT I.D.
------------  -------  -------  -------  ------------  -------------  -------------  ----------  ----------  ----------  ----------
           1   163948   155150   103370    1619080.26      723562.74         178.62                               -0.04  VPP 7-1
           2   163974   154927   103421    1619076.97      723567.45         179.87       -0.05        0.17              HPP 7-A
           3   166045   179356    98801    1619328.32      722972.61          63.75       -0.10       -0.43              HPP 7-B
           4   162723   180300    98839    1619416.55      722991.74          64.94                                0.11  VPP 7-2
           5   221058   156570   102618    1617768.91      722831.94         157.15                                0.21  VPP 8-1
           6   226046   181879    98772    1617962.34      722181.21          61.68        0.15        0.26              HPP 8-A
           7   223176   181457    98766    1618024.12      722226.34          61.80                               -0.29  VPP 8-2

STANDARD DEVIATION OF RESIDUALS.     X =   0.14     Y =   0.37     Z=   0.22
NUMBER OF ITERATIONS REQUIRED FOR SOLUTION =  3
DEGREES OF FREEDOM =  3
MODEL SCALE = 1/    3233.9265
OMEGA(88) = -0.43
PHI(88) =  0.31
EACH POINT WAS DIGITIZED 3 TIMES.


           MANUSCRIPT DIMENSIONS     XPLOTTER = 14.0 INCHES     YPLOTTER =  6.1 INCHES
           ---------------------------------------------------------------------------

                         GRID TICKS HAVE BEEN PLOTTED
                         ----------------------------
                           SEARCH RECORD NUMBER  1

                         GRID TICKS HAVE BEEN LABELED
                         ----------------------------
                           SEARCH RECORD NUMBER  2

                         CONTROL POINTS HAVE BEEN PLOTTED
                         --------------------------------
                           SEARCH RECORD NUMBER  3

                         TITLE, SCALE, AND NORTH ARROW HAVE BEEN PLOTTED
                         -----------------------------------------------
                           SEARCH RECORD NUMBER  4
                           PEN NUMBER 1
```

Figure 9. Task 1 printer listing

of the digitized points to ground or state plane coordinates using the parameters which will be established from the control points digitized for task 1. Once a digitized point has been converted to a ground or state plane coordinate in units of feet, it can easily be converted to the various other formats required by engineers such as profiles, cross-sections, areas, slope distances, etc. The purpose of the remaining four tasks is to provide these various formats of ground data in both digital and graphical form.

Task 2 (Random Points) is for digitizing random photo identifiable point features such as drill holes, trees, property corners, etc. The printer listing as shown in Figure 10 provides a state plan coordinate and an elevation for each digitized point. An identification number for each point can be entered into the fixed data switches of the digitizing console and will also be reflected on the printer listing for identification purposes if necessary. The Calcomp plot will reflect a symbol or spot elevation in the correct coordinate location. The choice of the appropriate symbol or spot elevation is selected by the stereoplotter operator entering the appropriate codes into the fixed data switches of the digitizing console. The Calcomp plot shown in Figure 8 shows the location of four power towers which have been plotted with Calcomp symbol number 7 .

Task 3 (Cross-sections) is for digitizing terrain cross-sections for engineering design, earthwork computation, hydraulic design, etc. A cross-section is a sequence of points in a straight line for which elevations and horizontal distances to a reference base line are known. The printer listing as shown in Figure 11 identifies each cross-section with a station value in feet which is entered by the stereoplotter operator into the fixed data switches of the digitizing console. For each digitized

RANDOM POINTS
****
MODEL NUMBER 6398

SEQUENCE NO.	X-MODEL	Y-MODEL	Z-MODEL	X-GRID(EAST)	Y-GRID(NORTH)	Z-GRID(ELEV.)	POINT I.D.	PLOT SYMBOL
1	215504	146501	108834	1617774.34	723135.17	318.68	0	7
2	215686	141113	109903	1617704.15	723258.50	345.58	0	7
3	186950	145826	110803	1618430.21	723500.03	371.15	0	7
4	189139	140412	110970	1618313.13	723599.28	374.29	0	7

EACH POINT WAS DIGITIZED 2 TIMES.

RANDOM POINTS HAVE BEEN PLOTTED FOR MODEL NO. 6398

SEARCH RECORD NUMBER 5
PEN NUMBER 1

Figure 10. Task 2 printer listing

```
CROSS SECTION
*************
MODEL NUMBER  6398
STATION     1+50
```

SEQUENCE NO.	X-MODEL	Y-MODEL	Z-MODEL	X-GRID(EAST)	Y-GRID(NORTH)	Z-GRID(ELEV.)	OFFSET DISTANCE
1	188844	205030	97307	1619111.05	722097.00	29.39	-756.01
2	188846	203218	97533	1619088.85	722139.18	34.94	-708.35
3	188846	201026	97423	1619062.08	722190.16	31.57	-650.77
4	188846	198490	97785	1619031.06	722249.23	40.52	-584.05
5	188846	196110	97725	1619002.00	722304.59	38.43	-521.52
6	188846	192326	97735	1618955.78	722392.63	37.86	-422.08
7	188846	188854	97353	1618913.42	722473.34	27.07	-330.93
8	188846	184878	97682	1618864.81	722565.91	34.84	-226.38
9	188846	182156	97915	1618831.53	722629.28	40.37	-154.80
10	188846	178376	98115	1618785.33	722717.27	44.80	-55.42
11	188844	176280	99679	1618759.57	722766.34	85.44	0.0
12	188846	173666	98846	1618727.70	722826.98	62.98	68.51
13	188846	168046	99054	1618659.03	722957.78	67.21	216.24
14	188846	160838	99197	1618570.97	723125.51	69.40	405.68
15	188846	156018	96483	1618512.44	723237.17	-2.98	531.75
16	188846	150930	93945	1618450.62	723355.09	-70.78	664.89
17	188846	147612	92979	1618410.22	723432.12	-96.89	751.87

```
 17 ELEVATION POINTS HAVE BEEN PLOTTED FOR X-SECTION     1+50
-----------------------------------------------------------------
SEARCH RECORD NUMBER  7
PEN NUMBER 1
```

Figure 11. Task 3 printer listing

point of the cross-section the printer listing contains a sequence number, state plane coordinates, an elevation, and a horizontal offset distance. The elevations are shown on the Calcomp plot in plan view to the nearest tenth of a foot. The station number which identifies the cross-section is plotted at the end of the sequence of elevation points. Three cross-sections are shown in Figure 8 plotted perpendicular to the alignments of the road and the railroad. This task also produces the digitized cross-section data in a specific IBM card format which can be used as direct input to other Corps of Engineers programs which process cross-section data. For example the cards produced by this task could be used as input to the Corps of Engineers earthwork quantity calculation program or the cross-section plot program. Task 3 has been utilized in production more than any of the other tasks, because of the frequent requirement for cross-section data during the design and construction phases of engineering projects. Whenever possible photogrammetric cross-section data is utilized in preference to field surveyed cross-section data because of the tremendous cost savings realized.

Task 4 (Bounded Areas) is for digitizing the perimeter of a feature which has area on a terrain surface such as a lake, cleared area, building, tree covered area, etc. The printer listing as shown in Figure 12 contains state plane coordinates, an elevation, and accumulated horizontal and slope distance from the first point for each digitized point along the perimeter of the bounded area. Following the above information is a total distance around the perimeter measured both in horizontal projection and parallel to the slope of the terrain. Also included on the printer listing is the area within the digitized perimeter expressed

```
BOUNDED AREA
************
MODEL NUMBER  6398
IDENTIFICATION NUMBER    0
SUB-TASK NUMBER 0
```

SEQUENCE NO.	X-MODEL	Y-MODEL	Z-MODEL	X-GRID(EAST)	Y-GRID(NORTH)	Z-GRID(ELEV.)	PLOT SYMBOL	DISTANCE(HORIZ)	DISTANCE(SLOPE)
1	170004	171280	100440	1619136.75	723112.95	104.93	21	0.0	0.0
2	170390	171264	100214	1619127.61	723108.56	98.97	21	10.14	11.76
3	170348	172050	100215	1619138.18	723090.79	99.17	21	30.83	32.45
4	171264	172206	100262	1619118.77	723075.98	100.41	21	55.25	56.90
5	171398	170922	100289	1619099.97	723104.22	100.84	21	89.18	90.83
6	172110	170914	100311	1619083.30	723095.71	101.39	21	107.89	109.55
7	172198	170176	100392	1619072.23	723111.82	103.36	21	127.44	129.20
8	171370	170064	100375	1619090.13	723124.54	102.91	21	149.39	151.16
9	171226	170766	100331	1619102.06	723109.96	101.91	21	168.23	170.03
10	170118	170636	100359	1619126.25	723126.52	102.65	21	197.55	199.35

```
TOTAL HORIZONTAL DISTANCE =        214.72
TOTAL SLOPE DISTANCE =        216.67
GRID AREA =          1545.6 SQUARE FEET
GRID ACREAGE =        0.035483
```

```
BOUNDED AREA NUMBER    0 HAS BEEN PLOTTED FOR MODEL NUMBER  6398
----------------------------------------------------------------
SEARCH RECORD NUMBER  9
PEN NUMBER 1
```

Figure 12. Task 4 printer listing

both in square feet and in acres. The digitized perimeter may be represented on the Calcomp plot in many different ways depending upon the options selected by the stereoplotter operator. For example the perimeter may be plotted with a straight line or a mathematically smoothed line connecting the digitized points. The perimeter may include a user selected symbol plotted at each digitized point or no symbol at all. In Figure 8 the houses to the north of the highway were plotted using task 4 and digitizing the corners of the houses. The options selected by the stereoplotter operator provided for a straight line connecting the digitized points without the plotting of symbols at the actual points.

Task 5 (Lineal Features) is for digitizing a feature of a linear nature such as a road, river, fence line, railroad, etc. The printer listing as shown in Figure 13 is almost identical to that for bounded areas using task 4 except that no area information is computed since a lineal feature does not necessarily close upon itself. The printer listing contains state plane coordinates, an elevation, and accumulated horizontal and slope distance from the first point for each digitized point of the lineal feature. The Calcomp plot of the lineal feature is similar to the plot of the bounded area using task 4 in that a straight line or a smoothed curve fit between digitized points may be selected by the stereoplotter operator. Also the operator may select a Calcomp symbol or no symbol to be plotted at the actual coordinate location of the digitized points. Both the highway and the railroad shown in Figure 8 were plotted using task 5. Both sides of the highway were plotted using the option for smooth curve fit between digitized points with no symbols plotted at the actual points. The railroad was plotted using

LINEAL FEATURE
****
MODEL NUMBER 6398
IDENTIFICATION NUMBER 0
SUB-TASK NUMBER 1

SEQUENCE NO.	X-MODEL	Y-MODEL	Z-MODEL	X-GRID(EAST)	Y-GRID(NORTH)	Z-GRID(ELEV.)	PLOT SYMBOL	DISTANCE(HORIZ)	DISTANCE(SLOPE)
1	233710	178552	99210	1617743.48	722165.33	72.22	21	0.0	0.0
2	231770	178520	99242	1617788.22	722189.78	73.11	21	50.99	50.99
3	229150	178424	99345	1617848.00	722224.04	75.88	21	119.88	119.95
4	226850	178356	99397	1617900.67	722253.73	77.30	21	180.35	180.43
5	223358	178236	99478	1617980.45	722299.19	79.51	21	272.17	272.27
6	219948	178098	99570	1618058.09	722344.07	82.01	21	361.85	361.99
7	217122	177978	99643	1618122.37	722381.40	83.99	21	436.18	436.35
8	214954	177874	99693	1618171.53	722410.31	85.35	21	493.22	493.40
9	211488	177782	99729	1618251.05	722454.79	86.38	21	584.33	584.52
10	205200	177490	99812	1618393.78	722538.41	88.69	21	749.75	749.95
11	200888	177356	99839	1618492.46	722594.21	89.50	21	863.12	863.33
12	197848	177154	99742	1618560.74	722636.03	87.01	21	943.18	943.43
13	194158	177020	99726	1618644.96	722684.22	86.67	21	1040.22	1040.46
14	190952	176824	99743	1618717.16	722727.94	87.17	21	1124.62	1124.87
15	186880	176614	99661	1618809.35	722782.56	85.10	21	1231.77	1232.04
16	182908	176350	99570	1618898.56	722837.20	82.77	21	1336.39	1336.68
17	178094	175982	99444	1619006.08	722904.55	79.53	21	1463.26	1463.60
18	175088	175714	99366	1619072.76	722947.49	77.52	21	1542.57	1542.94
19	172132	175430	99275	1619138.08	722990.19	75.15	21	1620.61	1621.01
20	168012	175056	99263	1619229.38	723049.22	74.88	21	1729.33	1729.73
21	163914	174604	99180	1619319.22	723109.78	72.73	21	1837.67	1838.09
22	160914	174306	99124	1619385.38	723153.35	71.29	21	1916.90	1917.33
23	157446	173892	99051	1619461.03	723205.33	69.39	21	2008.68	2009.13
24	154192	173530	98982	1619532.33	723253.49	67.59	21	2094.72	2095.19
25	152654	173422	98938	1619566.80	723274.78	66.46	21	2135.24	2135.72

TOTAL HORIZONTAL DISTANCE = 2135.24
TOTAL SLOPE DISTANCE = 2135.72

LINEAL FEATURE NUMBER 0 HAS BEEN PLOTTED FOR MODEL NUMBER 6398

SEARCH RECORD NUMBER 16
PEN NUMBER 1

Figure 13. Task 5 printer listing

the options for a smooth curve fit between points and Calcomp symbol number 13 which is a vertical line plotted at the actual location of the digitized point. The plotting of the railroad is a good example of how the graphic capabilities of PHOTDIG are unlimited if the stereoplotter operator understands all the options of the program and applies some imagination in using them.

CHAPTER IV

CONCLUSION

PRODUCTION APPLICATIONS

The system has been successfully used in the Photogrammetry Section of the Portland District Army Corps of Engineers since November of 1975. Several minor software bugs have been resolved and some new options within the five tasks of PHOTDIG have been added. The system has been used to obtain design cross-sections, earthwork cross-sections, hydraulic cross-sections for flood plain studies, and data acquisition for environmental studies. The system has also been used to digitize and plot spot elevations in areas too flat for adequate description of the terrain using contours. It is estimated that the system has been utilized in production applications for approximately 2,600 hours of continuous use since it was first implemented in November of 1975.

One interesting application of the system related to an environmental study performed by the Portland District Corps of Engineers at Depoe Bay, Oregon. The Environmental Resources Branch of the Portland District was assigned the task of preparing a report on the environmental effects of depositing dredging spoils from the inner harbor of Depoe Bay to the outer harbor area. One of the environmental concerns was the possible adverse effect of the dredging spoils on the Bull Kelp population of the outer harbor of Depoe Bay. To monitor the Bull Kelp, large scale color aerial photography was taken of the outer harbor before disposal of dredging spoils and twice afterwards. Because of the large scale of the photography and the still condition of the ocean surface hundreds of individual kelp plants were visible on the photography. The individual kelp plants were digitized using the random point routine and the shoreline of the outer harbor was digitized using the lineal feature routine. For each of the three dates of photography a map showing the density and distribution of the kelp was automatically produced by the Calcomp plotter as a final product of the digitizing system. The three computer plots were of sufficient quality to be incorporated into the report directly without requiring any manual redrafting. For more information on this specific application or to review the computer maps the reader should consult Corps of Engineers (12).

BENEFITS OF THE SYSTEM

The described system has benefited the Portland District Corps of Engineers substantially. The primary benefit has been the savings in cost. It is estimated that the use of the programmable calculator to assist the stereoplotter operator in establishing absolute orientation has saved an average of one hour for each stereomodel compiled conventionally to produce a contour map. Assuming an effective hourly rate to twenty-five dollars for the stereoplotter and the operator, and that in a typical year 50 stereomodels are mapped, an annual savings of $1,250 is realized for just utilizing this portion of the system.

Another significant savings has been realized by the mathematics of PHOTDIG which permits the stereoplotter operator to digitize terrain data without establishing an absolute orientation. Also the Calcomp plotting capabilities of PHOTDIG have eliminated the need for manual plotting of the terrain data in many applications. It is estimated that these special features of PHOTDIG have saved at least two hours of stereoplotter time for each stereomodel utilized for photogrammetric digitizing. Assuming the same hourly rate of twenty-five dollars and that in a typical year approximately 80 stereomodels are used to digitize terrain data, an annual cost saving of $2,000 is realized. This saving is due to the sophistication of the computer program PHOTDIG, therefore the annual depreciation of the digitizing console and related equipment should not be subtracted from the $2,000. The digitizing equipment and the stereoplotter would be required even if PHOTDIG had not been developed and less sophisticated software had to be utilized instead. The Calcomp plotter was acquired by the Portland District Data Processing Office before the development of PHOTDIG and serves many other offices of the Portland District besides the Photogrammetry Section. PHOTDIG was developed to take maximum advantage of an already existing well equipped data processing facility.

In addition to the cost savings mentioned above which can be easily computed, there have been less tangible benefits which have increased the efficiency of the Portland District Photogrammetry Section. There has definitely been an increase in employee morale as a result of using the latest technology in equipment, software, and procedures. Before the implementation of this system the Portland District was dependent on other districts of the Corps of Engineers to furnish photogrammetric digitizing services. Not only did this adversely affect the morale of the Photogrammetry Section, but it also created problems of scheduling and responsiveness to deadlines in that the jobs of the Portland District would take second priority to the jobs of the other districts. Now the Portland District can perform the acquisition of digital photogrammetric terrain data inhouse with complete responsiveness to internal priorities.

FUTURE TRENDS

The trend in photogrammetric digitizing systems during the last several years has been towards the use of more powerful computers in direct interface with the stereoplotter. This trend has been primarily due to the availability of large capacity minicomputers at lower prices. As the price of minicomputers becomes lower, it becomes economically feasible to have a medium sized computer dedicated to a single application such as a photogrammetric digitizing system. For example if a 90 kilobyte minicomputer with a FORTRAN compiler could eventually be purchased for the same price as the Hewlett Packard programmable calculator used in this system, it would be much wiser to purchase the minicomputer instead of the programmable calculator. If this were done, the high level processing power of PHOTDIG which requires 90 kilobytes of storage, could be executed online with the photogrammetric digitizing system, instead of hand carrying the magnetic tape to a centralized data processing facility and waiting as long as a day for the printer listing and plot tape.

The Portland District is considering the acquisition of a second digitizing system for use with an existing second stereoplotter. For this system the use of a Tektronix 4051 minicomputer is being considered instead of the Hewlett Packard programmable calculator. The Tektronix

4051 is an eight kilobyte computer which programs in basic and has a CRT display which provides for a powerful graphics plotting capability under program control. The Tektronix 4051 would be purchased with a data communications option which would allow it to communicate with the Corps of Engineers IBM 370. The data communication option is reasonably priced and would eliminate the need for a 9-track tape recorder and hand carrying the tapes to the centralized data processing facility. The cost of the Tektronix 4051 is less than the combined cost of the Hewlett Packard programmable calculator and the 9-track tape recorder. The Tektronix computer uses large capacity magnetic tape cartridges which could be used for the temporary storage and editing of the digitized data before transmitting the data to the IBM 370 for processing by PHOTDIG. The larger capacity and higher level language of the Tektronix computer would permit more sophisticated routines to be used for online processing. The graphics capability of the CRT display would provide for more effective user oriented routines for editing the digitized data. The variation in the selection of the hardware components for the second system is a prime example of how a system concept must be dynamic and flexible to exploit the rapidly changing technologies of this modern age.

REFERENCES

1. Whitmore, George D., "Introduction to Photogrammetry", Manual of Photogrammetry, Volume I, pp. 1-11, 1965.

2. Doyle, Frederick J., "Analytical Photogrammetry", Manual of Photogrammetry, Volume I, pp. 463-464, 1965.

3. Waggoner, Claude W., Determination of Earthwork Pay Quantities by First-Order Photogrammetric Surveys and Electronic Processing of the Data, Walla Walla District, Corps of Engineers, 1964.

4. Waggoner, Claude W., Report on Determination of Earthwork Pay Quantities by First-order Photogrammetric Surveys and Electronic Processing of the Data, Walla Walla District, Corps of Engineers, 1960.

5. Wood, Kendall B., Gross, Spencer B, and MacPherson, Cullen H., "Automation of the Wild Al- Plotter," Proceedings of the 40th Annual Meeting, American Society of Photogrammetry, March, 1974.

6. Dorrer, Egon and Kurtz, B., "Plotter Interfaced With a Calculator," Photogrammetric Engineering, pp. 1065-1076, October, 1973.

7. Dorrer, Egon, Lander, E., and Toraskar, K. V., "Analog to Hybrid Stereoplotter," Photogrammetric Engineering, pp. 271-279, March, 1974.

8. Howell, Tomie F., "Automated Mapping System Implementation," Photogrammetric Engineering, pp. 1435-1446, December, 1974.

9. Wolf, Paul R., Elements of Photogrammetry, McGraw-Hill, 1974.

10. Hewlett Packard, Hewlett Packard 9810A Calculator Operating and Programming, 1971

11. Gorshe, Frank R., Reduction of Photogrammetrically Digitized Three-Dimensional Data (PHOTDIG), Portland District, Corps of Engineers, November, 1975.

12. Corps of Engineers, Intertidal Disposal of Dredged Materials at Depoe Bay, Oregon, Portland District, Corps of Engineers, October, 1978.

APPENDIX A

USERS INSTRUCTIONS FOR PHOTOGRAMMETRIC ROUTINES FOR HEWLETT PACKARD 9810A PROGRAMMABLE CALCULATOR

General Photogrammetric Routines for Hewlet Packard 9810A
Calculator, Altec AC-74 Digitizer, & Wild B8 Stereoplotter
By Frank Gorshe, January 1976
Portland District, Corps of Engineers.
Program Number P-1

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General Operation

Load Program - All the following routines are contained on one 10" magnetic card, labeled Program P-1. Key FMT, GO TO. Insert first and second side of magnetic card. After calculator has read second side of card program execution will automatically begin by printing Program Identification on thermal printer. Program will stop with 1's displayed in Registers X, Y, & Z. Routine 1 may now be entered by keying CONTINUE or the user may transfer to the routine of his choice as described in the following paragraph.

Routine Selection - Once the program is loaded the user may transfer to any of the available routines by keying STOP, END, GO TO, LABEL, Routine #. For example if the user wanted to enter Routine 4 for Slope Calculation he would key STOP, END, GO TO, LABEL, 4. Keying STOP & END before GTO, LABEL, Routine #, is not always required, but should be done as a matter of habit unless the user is familiar with the programming of the calculator.

Storing Parameters - Some of the routines require that the user store parameters such as model scale or base in one of the numbered storage registers of the calculator. This is accomplished by keying the number, X→( ), Register #. For example to store a plotter base of 15.13 in Register Ø62 the user would key 15.13, X→( ), Ø62. The register number keyed must always be the full 3 digit number including any leading zeros. To verify what is stored in Register Ø62 key X←( ), Ø62. The stored number will appear in Register X. From now on Register will be abbreviated with an R. For example Register Ø61 will be written as R(Ø61).

Routine 1 - Control Input

Allows for input of coordinates and elevations for up to 20 control points. Control points are held in calculator storage for use in other routines and are referenced by a sequential control point #.

1. Key STOP, END, GO TO, LABEL, 1, CONTINUE. Control headings are printed.

2. Read Control Point Sequence # of the next control point to be entered in Registers X, Y, & Z. If a Control Point of a different sequence number is to be entered, enter the new sequence # and key so that the new sequence # is seen in Register Y.

3. Enter North Coordinate (enter Ø if unknown). Key CONTINUE.

4. Enter East Coordinate (enter Ø if unknown). Key CONTINUE.

5. Enter Elevation (enter Ø if unknown). Key CONTINUE.

6. Sequence #, North Coordinate, East Coordinate and Elevation are printed. Read sequence number of next control point to be entered. Return to step 2 if another control point is to be entered.

NOTE: Control Points and other parameters stored in calculator may be stored on a magnetic card by keying FMT, X→( ) and inserting both sides of a 6" card or one side of a 10" card. This allows for saving stored values before turning calculator off. To re-input data from card to calculator key FMT, X←( ) and insert card.

Routine 2 - Scale & Level

Allows for quicker absolute orientation by digitizing 2 control points for calculation of base distance and changes to common omega & common Phi.

1. Store desired proportional model scale in R(Ø61). Store present plotter base setting in R(Ø62). Store control values in calculator using Routine 1.

2. Key STOP, END, GO TO, LABEL, 2, CONTINUE. Control point headings are printed.

3. Enter Control Point Sequence # of first point to be digitized. Key CONTINUE. Control values of first point are printed.

4. Enter Control Point Sequence # of second point to be digitized. Key CONTINUE. Control values of second point are printed. Registers XYZ go blank.

5. Digitize first control point. Desired scale and present base are printed.

6. Digitize second control point. Present model scale, new base setting, Omega change in grads, and Phi change in grads are printed. Make appropriate adjustments to plotter. Store new base setting in R(Ø62) and return to step 3 if another iteration is required.

NOTE: Although values for new base, Omega, and Phi are always calculated and printed, they are not all necessarily valid. For example if the 2 digitized control points were only vertical points then the new base setting would be invalid. If the two digitized vertical points were far apart along the Y axis of the plotter, but close along the X axis, then one would expect a valid Omega change value and not so valid Phi change value.

Routine 3 - Verify Control & Parameters

Allows for a printer listing of stored control values and stored parameters. For each control point the Sequence #, North and East Coordinates, and Elevation are printed. In addition scale, kappa (rotation angle), translation constants, and base are printed.

1. STOP, END, GO TO, LABEL, 3, CONTINUE. Read 2Ø in Register X. If less than 2Ø control points are to be listed, enter the sequence # of the last control point to be listed.

2. Key CONTINUE. Control headings, control values, and parameters are printed.

Routine 4 - Slope Calculation

Allows for online printing and display of calculated slope percentage after digitizing 2 terrain points in model.

1. Stereomodel should be relatively oriented and leveled, but need not be of an even scale.

2. STOP, END, GO TO, LABEL, 4, CONTINUE. Routine title is printed and 4's are displayed for verification of routine.

3. Key CONTINUE. Display goes blank.

4. Digitize first terrain point.

5. Digitize second terrain point. Percentage of slope from first to second point is printed and displayed for 3 seconds. Return to step 4 for another slope calculation.

Routine 5 - Index on Vertical Point

Allows for indexing on a vertical point before using Routine 6 for an online elevation display.

1. Stereomodel should be leveled, but need not be of an even scale. Present model scale should be stored in R (Ø61). If not known, execute Routine 7 before continuing. Control point values must be stored in calculator.

2. STOP, END, GO TO, LABEL, 5, CONTINUE. Control headings are printed and 5's are displayed to verify routine.

3. Enter Control Point Sequence # of vertical point to be indexed on. Key CONTINUE. Control values are printed. Displays go blank.

4. Digitize vertical control point to be indexed on. Model scale and translation constants are printed. Read 6's in display indicating start of Routine 6. If Routine 6 is desired key CONTINUE. Displays go blank. Each time a point is digitized the actual elevation will be displayed to the nearest tenth of a foot.

Routine 6 - Elevation Display

Allows for 1 second elevation display to the nearest tenth of a foot each time a terrain point is digitized.

1. Routine 5 must have been previously executed for calculation of translation constant.

2. STOP, END, GO TO, LABEL, 6, CONTINUE. Read 6's in display for verification of routine. If display other than to the nearest tenth is desired, key FIX ( ), N. (N = number of decimal places desired. For integer display, N = Ø)

3. Key CONTINUE. Displays go blank. Each time a point is now digitized the elevation in feet will be displayed for 1 second.

Routine 7 - Index on 2 Horizontal Points

Allows for digitizing 2 horizontal control points for computation of model scale, rotation angle kappa, and horizontal translation constants. Execution of this routine is done in preparation for Routine 8.

1. Control point values have been stored in calculator using Routine 1. Stereomodel should be leveled, but need not be of an even scale.

2. STOP, END, GO TO, LABEL, 7, CONTINUE. Control headings are printed and 7's are displayed to verify routine.

3. Enter Control Point Sequence # of first horizontal control point to be digitized (for maximum accuracy select first point near points to be later measured using Routine 8). Key CONTINUE. Control values of first point are printed.

4. Enter Control Point Sequence # of second horizontal control point to be digitized. Key CONTINUE. Control values of second point are printed.

5. Digitize first control point.

6. Digitize second control point. Calculated transformation parameters are printed and stored in appropriate registers in preparation for Routine 8. Read 8's in display indicating start of Routine 8. If desired, key CONTINUE.

Routine 8 - Measure Grid Coordinates & Elevations

Prints event counter #, grid coordinates, and elevation each time a terrain point is digitized. New headings are printed each time digitizer event counter is reset to 1.

1. Routine 5 has been executed for calculation of elevation parameters. Routine 7 has been executed for calculation of horizontal parameters.

2. STOP, END, GO TO, LABEL, 8, CONTINUE. Read 8's in display to verify routine.

3. Key CONTINUE. Routine title and headings are printed. Displays go blank. Set digitizer event counter to 1 or desired starting number.

4. Digitize terrain points. Each time a point is digitized the current event #, the North Coordinate, the East Coordinate, and the elevation of the point will be printed. If the event counter is reset to 1, new headings will be printed the next time a point is digitized.

NOTE: This routine may allow the stereoplotter to be also used as an XY table top digitizer by placing a map under the tracing table or a reduced film positive of the map in one of the plate carriers of the plotter. In this case only Routine 7 need be executed before using Routine 8.

ROUTINE F - List Raw Digitized Data

Prints headings and lists raw digitized data (Fixed Data, Event, X, Y, & Z) when digitizing data on magnetic tape for IBM 360/50 processing.

1. STOP, END, F(DEFINABLE). Headings are printed for fixed data, event counter, X, Y, & Z.

2. Each time a point is digitized fixed data, event #, X, Y, & Z are printed beneath appropriate headings. If the event counter is reset to 1 or the task code number is changed on the digitizer, new headings will be printed when the next point is digitized.

APPENDIX B

SOURCE LISTING OF PHOTOGRAMMETRIC ROUTINES FOR HEWLETT PACKARD 9810A PROGRAMMABLE CALCULATOR

```
0000--FMT---42
0001-- 4 ---04
0002-- . ---21
0003-- 1 ---01
0004-- 0 ---00
0005-- . ---21
0006-- 2 ---02
0007--FMT---42
0008-- 4 ---04
0009-- 8 ---10
0010--FMT---42
0011--CLR---20
0012--CLR---20
0013--CLR---20
0014-- * ---36
0015-- * ---36
0016-- * ---36
0017-- * ---36
0018--PI ---56
0019-- A ---13
0020-- O ---71
0021-- G ---15
0022-- A ---13
0023-- A ---62
0024-- M ---70
0025--CNT---47
0026--PI ---56
0027-- - ---34
0028-- 1 ---01
0029-- . ---21
0030--CNT---47
0031--CNT---47
0032-- G ---15
0033-- E ---60
0034-- N ---73
0035-- E ---60
0036-- A ---13
0037-- A ---62
0038-- L ---72
0039--CNT---47
0040--PI ---56
0041--1/X---17
0042-- A ---13
0043--PI ---56
0044-- O ---71
0045--YTO---40
0046-- E ---60
0047--CNT---47
0048--PI ---56
0049-- H ---74
0050-- O ---71
0051--XTO---23
0052-- O ---71
0053-- G ---15
0054-- A ---13
0055-- A ---62
0056-- M ---70
0057-- M ---70
0058-- E ---60
0059--XTO---23
0060-- A ---13
0061-- I ---65
0062-- C ---61
0063--CNT---47
0064-- A ---13
0065-- O ---71
0066--1/X---17
0067--XTO---23
0068-- I ---65
0069-- N ---73
0070-- E ---60
0071--YTO---40
0072-- . ---21
0073-- * ---36
0074-- * ---36
0075-- * ---36
0076-- * ---36
0077--CLR---20
0078--CNT---47
0079--CNT---47
0080--CNT---47
0081--CNT---47
0082-- B ---66
0083--XFR---67
0084--CNT---47
0085-- F ---16
0086-- A ---13
0087-- A ---62
0088-- N ---73
0089-- K ---55
0090--CNT---47
0091-- G ---15
0092-- O ---71
0093-- A ---13
0094--YTO---40
0095-- H ---74
0096-- E ---60
0097-- . ---21
0098--CNT---47
0099--CNT---47
0100-- J ---75
0101-- A ---62
0102-- N ---73
0103--1/X---17
0104-- A ---62
0105-- A ---13
0106--XFR---67
0107--CNT---47
0108-- 1 ---01
0109-- 9 ---11
0110-- 7 ---07
0111-- 6 ---06
0112-- . ---21
0113--CLR---20
0114--CLR---20
0115--CLR---20
0116--CLR---20
0117--FMT---42
0118-- 1 ---01
0119--UP ---27
0120--UP ---27
0121--STP---41
0122--GTO---44
0123--LBL---51
0124-- 1 ---01
0125--LBL---51
0126-- A ---62
0127--FMT---42
0128-- 3 ---03
0129-- 3 ---03
0130-- . ---21
0131--UP ---27
0132-- 1 ---01
0133-- 0 ---00
0134--DIV---35
0135--YTO---40
0136-- A ---13
0137--EEX---26
0138-- 3 ---03
0139--DIV---35
0140--XEY---30
0141--INT---64
0142--XTO---23
0143-- 7 ---07
0144-- 0 ---00
0145-- * ---36
0146-- A ---13
0147--XEY---30
0148-- - ---34
0149--YTO---40
0150-- A ---13
0151--EEX---26
0152-- 2 ---02
0153--DIV---35
0154--XEY---30
0155--INT---64
0156--XTO---23
0157-- 7 ---07
0158-- 1 ---01
0159-- * ---36
0160-- A ---13
0161--XEY---30
0162-- - ---34
0163--YTO---40
0164-- 7 ---07
0165-- 2 ---02
0166--FMT---42
0167-- 3 ---03
0168-- 3 ---03
0169-- . ---21
0170--UP ---27
0171--EEX---26
0172-- 2 ---02
0173--DIV---35
0174--YTO---40
0175-- A ---13
0176--EEX---26
0177-- 6 ---06
0178--DIV---35
0179--XEY---30
0180--INT---64
0181--XTO---23
0182-- 7 ---07
0183-- 3 ---03
0184-- * ---36
0185-- A ---13
0186--XEY---30
0187-- - ---34
0188--YTO---40
0189-- A ---13
0190--EEX---26
0191-- 2 ---02
0192--DIV---35
0193--XEY---30
0194--INT---64
0195--XTO---23
0196-- 7 ---07
0197-- 4 ---04
0198-- * ---36
0199-- A ---13
```

```
0200--KEY---30
0201-- - ---34
0202--YTO---40
0203-- 7 ---07
0204-- 5 ---05
0205--FMT---42
0206-- 3 ---03
0207-- 3 ---03
0208-- . ---21
0209--UP ---27
0210--EEX---26
0211-- 5 ---05
0212--DIV---35
0213--YTO---40
0214-- 7 ---07
0215-- 6 ---06
0216--FMT---42
0217-- 3 ---03
0218-- 3 ---03
0219-- . ---21
0220--UP ---27
0221--EEX---26
0222-- 3 ---03
0223--DIV---35
0224--YTO---40
0225-- 7 ---07
0226-- 7 ---07
0227--FMT---42
0228-- 3 ---03
0229-- 3 ---03
0230-- . ---21
0231--UP ---27
0232--EEX---26
0233-- 3 ---03
0234--DIV---35
0235--YTO---40
0236-- 7 ---07
0237-- 8 ---10
0238--FMT---42
0239-- 3 ---03
0240-- 3 ---03
0241-- . ---21
0242--UP ---27
0243--EEX---26
0244-- 3 ---03
0245--DIV---35
0246--YTO---40
0247-- 7 ---07
0248-- 9 ---11
0249--S/R---77
0250--LBL---51
0251-- B ---66
0252--FMT---42
0253-- 4 ---04
0254-- 8 ---10
0255--FMT---42
0256--CLR---20
0257--CLR---20
0258--CLR---20
0259--CLR---20
0260--CLR---20
0261--CNT---47
0262--CNT---47
0263--CNT---47
0264--CNT---47
0265-- M ---70
0266-- O ---71
0267-- D ---63
0268-- E ---60
0269-- L ---72
0270--CNT---47
0271--CNT---47
0272--CNT---47
0273-- D ---63
0274-- E ---60
0275-- L ---72
0276-- E ---60
0277--XTO---23
0278-- E ---60
0279--CNT---47
0280--CNT---47
0281--CNT---47
0282--XTO---23
0283-- A ---62
0284--YTO---40
0285-- K ---55
0286--CNT---47
0287--CNT---47
0288--CNT---47
0289--YTO---40
0290--1/X---17
0291-- B ---66
0292--XTO---23
0293-- A ---62
0294--YTO---40
0295-- K ---55
0296--CNT---47
0297--CNT---47
0298-- I ---65
0299-- D ---63
0300-- E ---60
0301-- N ---73
0302--XTO---23
0303--CNT---47
0304--CNT---47
0305--YTO---40
0306--1/X---17
0307-- B ---66
0308-- - ---34
0309-- I ---65
0310-- D ---63
0311--CNT---47
0312--CNT---47
0313--CNT---47
0314-- E ---60
0315--INT---64
0316-- E ---60
0317-- N ---73
0318--XTO---23
0319--CNT---47
0320--CNT---47
0321--CNT---47
0322--YE ---24
0323--CNT---47
0324--CNT---47
0325--CNT---47
0326--CNT---47
0327--CNT---47
0328--CNT---47
0329--CNT---47
0330--XFR---67
0331--CNT---47
0332--CNT---47
0333--CNT---47
0334--CNT---47
0335--CNT---47
0336--CNT---47
0337--CNT---47
0338--XSQ---12
0339--CNT---47
0340--CNT---47
0341--CLR---20
0342--FMT---42
0343--S/R---77
0344--LBL---51
0345-- C ---61
0346--FMT---42
0347-- 4 ---04
0348-- 8 ---10
0349--FMT---42
0350--CLR---20
0351--CLR---20
0352--CLR---20
0353--CLR---20
0354--PI ---56
0355-- O ---71
0356-- I ---65
0357-- N ---73
0358--XTO---23
0359--CNT---47
0360-- N ---73
0361--1/X---17
0362-- M ---70
0363-- B ---66
0364-- E ---60
0365-- A ---13
0366--CNT---47
0367--CNT---47
0368--CNT---47
0369--CNT---47
0370--CNT---47
0371--CNT---47
0372-- N ---73
0373-- O ---71
0374-- A ---13
0375--XTO---23
0376-- H ---74
0377--CNT---47
0378--CNT---47
0379--CNT---47
0380--CNT---47
0381--CNT---47
0382--CNT---47
0383--CNT---47
0384--CNT---47
0385--CNT---47
0386--CNT---47
0387-- E ---60
0388-- A ---62
0389--YTO---40
0390--XTO---23
0391--CNT---47
0392--CNT---47
0393--CNT---47
0394--CNT---47
0395--CNT---47
0396--CNT---47
0397--CNT---47
0398--CNT---47
0399--CNT---47
```

```
0400--CNT---47
0401-- E ---60
0402-- L ---72
0403-- E ---60
0404--INT---64
0405-- A ---62
0406--XTO---23
0407-- I ---65
0408-- O ---71
0409-- N ---73
0410--CLR---20
0411--FMT---42
0412--S/R---77
0413--LBL---51
0414-- G ---15
0415--UP ---27
0416-- 3 ---03
0417-- * ---36
0418--YTO---40
0419-- A ---13
0420--XFR---67
0421--IND---31
0422-- A ---13
0423--UP ---27
0424-- 1 ---01
0425--XTO---23
0426-- - ---34
0427-- A ---13
0428--XFR---67
0429--IND---31
0430-- A ---13
0431--UP ---27
0432-- 1 ---01
0433--XTO---23
0434-- - ---34
0435-- A ---13
0436--XFR---67
0437--IND---31
0438-- A ---13
0439--S/R---77
0440--LBL---51
0441-- 7 ---07
0442-- K ---55
0443-- 1 ---01
0444--GTO---44
0445--S/R---77
0446--LBL---51
0447-- C ---61
0448-- 7 ---07
0449--UP ---27
0450--UP ---27
0451--STP---41
0452--XTO---23
0453-- 6 ---06
0454-- 7 ---07
0455--GTO---44
0456--S/R---77
0457--LBL---51
0458-- D ---63
0459-- 2 ---02
0460--UP ---27
0461--UP ---27
0462--STP---41
0463--XTO---23
0464-- 6 ---06
0465-- 8 ---10
0466--GTO---44
0467--S/R---77
0468--LBL---51
0469-- D ---63
0470-- 1 ---01
0471--XTO---23
0472-- 6 ---06
0473-- 1 ---01
0474--GTO---44
0475--S/R---77
0476--LBL---51
0477-- E ---60
0478--XFR---67
0479-- 8 ---10
0480-- 7 ---07
0481--XTO---23
0482-- 8 ---10
0483-- 5 ---05
0484--XFR---67
0485-- 8 ---10
0486-- 8 ---10
0487--XTO---23
0488-- 8 ---10
0489-- 6 ---06
0490--FMT---42
0491-- 4 ---04
0492-- 8 ---10
0493--FMT---42
0494--CLR---20
0495--FMT---42
0496--GTO---44
0497--S/R---77
0498--LBL---51
0499-- E ---60
0500--XFR---67
0501-- 8 ---10
0502-- 8 ---10
0503--UP ---27
0504--XFR---67
0505-- 8 ---10
0506-- 7 ---07
0507--YE ---24
0508-- - ---34
0509-- 8 ---10
0510-- 6 ---06
0511--XFR---67
0512-- - ---34
0513-- 8 ---10
0514-- 5 ---05
0515-- A ---62
0516--XTO---23
0517-- 8 ---10
0518-- 7 ---07
0519--YTO---40
0520-- 8 ---10
0521-- 8 ---10
0522--XFR---67
0523-- 6 ---06
0524-- 7 ---07
0525--GTO---44
0526--S/R---77
0527--LBL---51
0528-- G ---15
0529--XTO---23
0530-- 1 ---01
0531-- 0 ---00
0532-- 4 ---04
0533--YTO---40
0534-- 1 ---01
0535-- 0 ---00
0536-- 5 ---05
0537--XFR---67
0538-- 6 ---06
0539-- 8 ---10
0540--GTO---44
0541--S/R---77
0542--LBL---51
0543-- G ---15
0544--XEY---30
0545--XFR---67
0546-- - ---34
0547-- 1 ---01
0548-- 0 ---00
0549-- 5 ---05
0550--YE ---24
0551-- - ---34
0552-- 1 ---01
0553-- 0 ---00
0554-- 4 ---04
0555-- A ---62
0556--XFR---67
0557--DIV---35
0558-- 8 ---10
0559-- 7 ---07
0560--XTO---23
0561-- 6 ---06
0562-- 1 ---01
0563--XEY---30
0564--XFR---67
0565-- - ---34
0566-- 8 ---10
0567-- 8 ---10
0568--CHS---32
0569--XTO---23
0570-- 6 ---06
0571-- 3 ---03
0572--DN ---25
0573--UP ---27
0574--XFR---67
0575-- * ---36
0576-- 8 ---10
0577-- 5 ---05
0578--XTO---23
0579-- 8 ---10
0580-- 7 ---07
0581--YE ---24
0582-- * ---36
0583-- 8 ---10
0584-- 6 ---06
0585--YTO---40
0586-- 8 ---10
0587-- 8 ---10
0588--CNT---47
0589-- 0 ---00
0590--XTO---23
0591-- 6 ---06
0592-- 4 ---04
0593--XTO---23
0594-- 6 ---06
0595-- 5 ---05
0596--GTO---44
0597--S/R---77
0598--LBL---51
0599-- I ---65
```

```
0600--XFR---67
0601-- 1 ---01
0602-- 0 ---00
0603-- 4 ---04
0604--XFR---67
0605-- - ---34
0606-- 1 ---01
0607-- 0 ---00
0608-- 1 ---01
0609--XTO---23
0610-- 6 ---06
0611-- 4 ---04
0612--XFR---67
0613-- 1 ---01
0614-- 0 ---00
0615-- 5 ---05
0616--XFR---67
0617-- - ---34
0618-- 1 ---01
0619-- 0 ---00
0620-- 2 ---02
0621--XTO---23
0622-- 6 ---06
0623-- 5 ---05
0624--GTO---44
0625--S/R---77
0626--LBL---51
0627-- K ---55
0628--GTO---44
0629--LBL---51
0630-- 8 ---10
0631--LBL---51
0632-- 8 ---10
0633--SFL---54
0634-- 8 ---10
0635--UP ---27
0636--UP ---27
0637--STP---41
0638--GTO---44
0639--S/R---77
0640--LBL---51
0641-- M ---70
0642--GTO---44
0643--S/R---77
0644--LBL---51
0645-- C ---61
0646--LBL---51
0647--YTO---40
0648--GTO---44
0649--S/R---77
0650--LBL---51
0651-- E ---60
0652--IFG---43
0653--GTO---44
0654--LBL---51
0655--YE ---24
0656--CNT---47
0657-- 1 ---01
0658--UP ---27
0659--XFR---67
0660-- 7 ---07
0661-- 6 ---06
0662--X=Y---50
0663--GTO---44
0664--S/R---77
0665--LBL---51
0666-- M ---70
0667--X=Y---50
0668--GTO---44
0669--S/R---77
0670--LBL---51
0671-- C ---61
0672--LBL---51
0673--YE ---24
0674--GTO---44
0675--S/R---77
0676--LBL---51
0677-- I ---65
0678--GTO---44
0679--S/R---77
0680--LBL---51
0681-- J ---75
0682--GTO---44
0683--LBL---51
0684--YTO---40
0685--LBL---51
0686-- M ---70
0687--FMT---42
0688-- 4 ---04
0689-- 8 ---10
0690--FMT---42
0691--CLR---20
0692--CLR---20
0693--CLR---20
0694--CLR---20
0695--CLR---20
0696-- M ---70
0697-- E ---60
0698-- A ---62
0699--YTO---40
0700--1/X---17
0701-- A ---13
0702-- E ---60
0703-- D ---63
0704--CNT---47
0705--PI ---56
0706-- O ---71
0707-- I ---65
0708-- N ---73
0709--XTO---23
0710--YTO---40
0711--CLR---20
0712--FMT---42
0713--S/R---77
0714--LBL---51
0715-- I ---65
0716-- K ---55
0717-- 1 ---01
0718--XFR---67
0719-- 6 ---06
0720-- 3 ---03
0721--UP ---27
0722-- M ---70
0723--XTO---23
0724-- A ---13
0725--DN ---25
0726-- N ---73
0727--XTO---23
0728-- B ---14
0729--XFR---67
0730-- 8 ---10
0731-- 9 ---11
0732--XFR---67
0733-- + ---33
0734-- 6 ---06
0735-- 6 ---06
0736--XTO---23
0737-- 1 ---01
0738-- 0 ---00
0739-- 3 ---03
0740--XFR---67
0741-- 8 ---10
0742-- 8 ---10
0743--UP ---27
0744--XFR---67
0745-- 8 ---10
0746-- 7 ---07
0747--XFR---67
0748-- * ---36
0749-- B ---14
0750--YE ---24
0751-- * ---36
0752-- A ---13
0753-- + ---33
0754--YE ---24
0755-- + ---33
0756-- 6 ---06
0757-- 5 ---05
0758--YTO---40
0759-- 1 ---01
0760-- 0 ---00
0761-- 2 ---02
0762--UP ---27
0763--XFR---67
0764-- 8 ---10
0765-- 8 ---10
0766--UP ---27
0767--XFR---67
0768-- 8 ---10
0769-- 7 ---07
0770--XFR---67
0771-- * ---36
0772-- A ---13
0773--YE ---24
0774-- * ---36
0775-- B ---14
0776-- - ---34
0777--YE ---24
0778-- + ---33
0779-- 6 ---06
0780-- 4 ---04
0781--YTO---40
0782-- 1 ---01
0783-- 0 ---00
0784-- 1 ---01
0785--DN ---25
0786--S/R---77
0787--LBL---51
0788-- J ---75
0789--FMT---42
0790-- 4 ---04
0791-- . ---21
0792-- 1 ---01
0793-- 0 ---00
0794-- . ---21
0795-- 0 ---00
0796--XFR---67
0797-- 7 ---07
0798-- 6 ---06
0799--FMT---42
```

```
0800-- 4 ---04
0801-- 8 ---10
0802--PNT---45
0803--FMT---42
0804-- 4 ---04
0805-- . ---21
0806-- 1 ---01
0807-- 5 ---05
0808-- . ---21
0809-- 1 ---01
0810--XFR---67
0811-- 1 ---01
0812-- 0 ---00
0813-- 1 ---01
0814--FMT---42
0815-- 4 ---04
0816-- 8 ---10
0817--PNT---45
0818--XFR---67
0819-- 1 ---01
0820-- 0 ---00
0821-- 2 ---02
0822--FMT---42
0823-- 4 ---04
0824-- 8 ---10
0825--PNT---45
0826--XFR---67
0827-- 1 ---01
0828-- 0 ---00
0829-- 3 ---03
0830--FMT---42
0831-- 4 ---04
0832-- 8 ---10
0833--FMT---42
0834--PNT---45
0835--CLR---20
0836--FMT---42
0837--S/R---77
0838--LBL---51
0839-- D ---63
0840--FMT---42
0841-- 4 ---04
0842-- . ---21
0843-- 1 ---01
0844-- 0 ---00
0845-- . ---21
0846-- 0 ---00
0847--FMT---42
0848-- 4 ---04
0849-- 8 ---10
0850--PNT---45
0851--FMT---42
0852-- 4 ---04
0853-- . ---21
0854-- 1 ---01
0855-- 5 ---05
0856-- . ---21
0857-- 2 ---02
0858--GTO---44
0859--S/R---77
0860--LBL---51
0861-- G ---15
0862--FMT---42
0863-- 4 ---04
0864-- 8 ---10
0865--PNT---45
0866--DN ---25
0867--FMT---42
0868-- 4 ---04
0869-- 8 ---10
0870--PNT---45
0871--DN ---25
0872--FMT---42
0873-- 4 ---04
0874-- 8 ---10
0875--PNT---45
0876--FMT---42
0877-- 4 ---04
0878-- 8 ---10
0879--FMT---42
0880--CLR---20
0881--FMT---42
0882--S/R---77
0883--LBL---51
0884-- K ---55
0885--FMT---42
0886-- 4 ---04
0887-- . ---21
0888-- 1 ---01
0889-- 2 ---02
0890-- . ---21
0891-- 3 ---03
0892--XFR---67
0893-- 6 ---06
0894-- 1 ---01
0895--FMT---42
0896-- 4 ---04
0897-- 8 ---10
0898--FMT---42
0899--CLR---20
0900--YTO---40
0901-- C ---61
0902-- A ---62
0903-- L ---72
0904-- E ---60
0905--PNT---45
0906--CLR---20
0907--FMT---42
0908--XFR---67
0909-- 6 ---06
0910-- 3 ---03
0911--FMT---42
0912-- 4 ---04
0913-- 8 ---10
0914--FMT---42
0915--CLR---20
0916-- K ---55
0917-- A ---62
0918--PI ---56
0919--PI ---56
0920-- A ---62
0921--PNT---45
0922--CNT---47
0923-- D ---63
0924-- E ---60
0925-- G ---15
0926--CLR---20
0927--FMT---42
0928--XFR---67
0929-- 6 ---06
0930-- 4 ---04
0931--FMT---42
0932-- 4 ---04
0933-- 8 ---10
0934--FMT---42
0935--CLR---20
0936--XTO---23
0937-- A ---13
0938-- A ---62
0939-- N ---73
0940--YTO---40
0941-- L ---72
0942-- A ---62
0943--XTO---23
0944-- I ---65
0945-- O ---71
0946-- N ---73
0947--CNT---47
0948-- C ---61
0949-- O ---71
0950-- N ---73
0951--YTO---40
0952--XTO---23
0953-- A ---62
0954-- N ---73
0955--XTO---23
0956--YTO---40
0957--CLR---20
0958-- N ---73
0959-- O ---71
0960-- A ---13
0961--XTO---23
0962-- H ---74
0963--PNT---45
0964--CLR---20
0965--FMT---42
0966--XFR---67
0967-- 6 ---06
0968-- 5 ---05
0969--FMT---42
0970-- 4 ---04
0971-- 8 ---10
0972--FMT---42
0973-- E ---60
0974-- A ---62
0975--YTO---40
0976--XTO---23
0977--PNT---45
0978--CLR---20
0979--FMT---42
0980--XFR---67
0981-- 6 ---06
0982-- 6 ---06
0983--FMT---42
0984-- 4 ---04
0985-- 8 ---10
0986--FMT---42
0987-- E ---60
0988-- L ---72
0989-- E ---60
0990--INT---64
0991--PNT---45
0992--CLR---20
0993--CLR---20
0994--FMT---42
0995--S/R---77
0996--LBL---51
0997-- E ---60
0998--GTO---44
0999--S/R---77
```

```
1000--LBL---51
1001-- A ---62
1002-- 1 ---01
1003--EEX---26
1004--CHS---32
1005-- 6 ---06
1006--UP ---27
1007-- . ---21
1008-- 3 ---03
1009-- 0 ---00
1010-- 4 ---04
1011-- 8 ---10
1012--DIV---35
1013--XFR---67
1014-- 6 ---06
1015-- 1 ---01
1016-- * ---36
1017--YTO---40
1018-- A ---13
1019--XFR---67
1020-- 7 ---07
1021-- 7 ---07
1022-- * ---36
1023--YTO---40
1024-- 8 ---10
1025-- 7 ---07
1026-- A ---13
1027--UP ---27
1028--XFR---67
1029-- 7 ---07
1030-- 8 ---10
1031-- * ---36
1032--YTO---40
1033-- 8 ---10
1034-- 8 ---10
1035-- A ---13
1036--UP ---27
1037--CNT---47
1038--CNT---47
1039--CNT---47
1040--XFR---67
1041-- 7 ---07
1042-- 9 ---11
1043-- * ---36
1044--YTO---40
1045-- 8 ---10
1046-- 9 ---11
1047--S/R---77
1048--LBL---51
1049-- F ---16
1050--GTO---44
1051--S/R---77
1052--LBL---51
1053-- B ---66
1054--FMT---42
1055-- 4 ---04
1056-- . ---21
1057-- 8 ---10
1058-- . ---21
1059-- 0 ---00
1060--SFL---54
1061--LBL---51
1062--PI ---56
1063--GTO---44
1064--S/R---77
1065--LBL---51
1066-- A ---62
1067--IFG---43
1068--GTO---44
1069--LBL---51
1070--INT---64
1071--CNT---47
1072-- 0 ---00
1073--XTO---23
1074-- A ---13
1075--XFR---67
1076-- 7 ---07
1077-- 6 ---06
1078--UP ---27
1079-- 1 ---01
1080--X=Y---50
1081--CNT---47
1082-- 1 ---01
1083--XTO---23
1084-- A ---13
1085--XFR---67
1086-- 7 ---07
1087-- 2 ---02
1088--UP ---27
1089-- B ---14
1090--X<Y---52
1091--CNT---47
1092-- 1 ---01
1093--XTO---23
1094-- A ---13
1095-- B ---14
1096--X>Y---53
1097--CNT---47
1098-- 1 ---01
1099--XTO---23
1100-- A ---13
1101-- 1 ---01
1102--UP ---27
1103-- A ---13
1104--X=Y---50
1105--GTO---44
1106--S/R---77
1107--LBL---51
1108-- B ---66
1109--LBL---51
1110--INT---64
1111--XFR---67
1112-- 7 ---07
1113-- 0 ---00
1114--FMT---42
1115-- 4 ---04
1116-- 8 ---10
1117--PNT---45
1118--XFR---67
1119-- 7 ---07
1120-- 1 ---01
1121--FMT---42
1122-- 4 ---04
1123-- 8 ---10
1124--PNT---45
1125--XFR---67
1126-- 7 ---07
1127-- 2 ---02
1128--FMT---42
1129-- 4 ---04
1130-- 8 ---10
1131--PNT---45
1132--XTO---23
1133-- B ---14
1134--XFR---67
1135-- 7 ---07
1136-- 3 ---03
1137--FMT---42
1138-- 4 ---04
1139-- 8 ---10
1140--PNT---45
1141--XFR---67
1142-- 7 ---07
1143-- 4 ---04
1144--FMT---42
1145-- 4 ---04
1146-- 8 ---10
1147--PNT---45
1148--XFR---67
1149-- 7 ---07
1150-- 5 ---05
1151--FMT---42
1152-- 4 ---04
1153-- 8 ---10
1154--PNT---45
1155--XFR---67
1156-- 7 ---07
1157-- 6 ---06
1158--FMT---42
1159-- 4 ---04
1160-- 8 ---10
1161--PNT---45
1162--XFR---67
1163-- 7 ---07
1164-- 7 ---07
1165--FMT---42
1166-- 4 ---04
1167-- 8 ---10
1168--PNT---45
1169--XFR---67
1170-- 7 ---07
1171-- 8 ---10
1172--FMT---42
1173-- 4 ---04
1174-- 8 ---10
1175--PNT---45
1176--XFR---67
1177-- 7 ---07
1178-- 9 ---11
1179--FMT---42
1180-- 4 ---04
1181-- 8 ---10
1182--PNT---45
1183--FMT---42
1184-- 4 ---04
1185-- 8 ---10
1186--FMT---42
1187--CLR---20
1188--FMT---42
1189--GTO---44
1190--LBL---51
1191--PI ---56
1192--S/R---77
1193--LBL---51
1194-- 1 ---01
1195--GTO---44
1196--S/R---77
1197--LBL---51
1198-- C ---61
1199-- 1 ---01
```

```
1200--XTO---23
1201-- 8 ---10
1202-- 3 ---03
1203--LBL---51
1204--XSQ---12
1205--XFR---67
1206-- 8 ---10
1207-- 3 ---03
1208--UP ---27
1209--UP ---27
1210--STP---41
1211--YTO---40
1212-- 8 ---10
1213-- 3 ---03
1214--XTO---23
1215-- A ---13
1216-- 3 ---03
1217-- * ---36
1218-- 2 ---02
1219-- - ---34
1220--YTO---40
1221-- 8 ---10
1222-- 4 ---04
1223-- A ---13
1224--XTO---23
1225--IND---31
1226-- 8 ---10
1227-- 4 ---04
1228--STP---41
1229--UP ---27
1230-- 1 ---01
1231--XTO---23
1232-- + ---33
1233-- 8 ---10
1234-- 4 ---04
1235--DN ---25
1236--XTO---23
1237--IND---31
1238-- 8 ---10
1239-- 4 ---04
1240--STP---41
1241--UP ---27
1242-- 1 ---01
1243--XTO---23
1244-- + ---33
1245-- 8 ---10
1246-- 4 ---04
1247--DN ---25
1248--XTO---23
1249--IND---31
1250-- 8 ---10
1251-- 4 ---04
1252--XFR---67
1253-- 8 ---10
1254-- 3 ---03
1255--GTO---44
1256--S/R---77
1257--LBL---51
1258-- D ---63
1259-- 1 ---01
1260--XTO---23
1261-- + ---33
1262-- 8 ---10
1263-- 3 ---03
1264--GTO---44
1265--LBL---51
1266--XSQ---12
1267--LBL---51
1268-- 2 ---02
1269--GTO---44
1270--S/R---77
1271--LBL---51
1272-- C ---61
1273--STP---41
1274--XTO---23
1275-- 8 ---10
1276-- 1 ---01
1277--GTO---44
1278--S/R---77
1279--LBL---51
1280-- D ---63
1281-- 2 ---02
1282--UP ---27
1283--UP ---27
1284--STP---41
1285--XTO---23
1286-- 8 ---10
1287-- 2 ---02
1288--GTO---44
1289--S/R---77
1290--LBL---51
1291-- D ---63
1292--GTO---44
1293--S/R---77
1294--LBL---51
1295-- E ---60
1296--XFR---67
1297-- 8 ---10
1298-- 7 ---07
1299--XTO---23
1300-- 9 ---11
1301-- 0 ---00
1302--XFR---67
1303-- 8 ---10
1304-- 8 ---10
1305--XTO---23
1306-- 9 ---11
1307-- 1 ---01
1308--XFR---67
1309-- 8 ---10
1310-- 9 ---11
1311--XTO---23
1312-- 9 ---11
1313-- 2 ---02
1314--FMT---42
1315-- 4 ---04
1316-- . ---21
1317-- 1 ---01
1318-- 2 ---02
1319-- . ---21
1320-- 3 ---03
1321--XFR---67
1322-- 6 ---06
1323-- 1 ---01
1324--FMT---42
1325-- 4 ---04
1326-- 8 ---10
1327--FMT---42
1328--CLR---20
1329-- D ---63
1330-- E ---60
1331--YTO---40
1332-- I ---65
1333-- A ---13
1334-- E ---60
1335-- D ---63
1336--CNT---47
1337--YTO---40
1338-- C ---61
1339-- A ---62
1340-- L ---72
1341-- E ---60
1342--PNT---45
1343--CLR---20
1344--FMT---42
1345--XFR---67
1346-- 6 ---06
1347-- 2 ---02
1348--FMT---42
1349-- 4 ---04
1350-- 8 ---10
1351--FMT---42
1352--PI ---56
1353-- A ---13
1354-- E ---60
1355--YTO---40
1356-- E ---60
1357-- N ---73
1358--XTO---23
1359--CNT---47
1360-- B ---66
1361-- A ---62
1362--YTO---40
1363-- E ---60
1364--PNT---45
1365--CLR---20
1366--CLR---20
1367--FMT---42
1368--GTO---44
1369--S/R---77
1370--LBL---51
1371-- E ---60
1372--XFR---67
1373-- 8 ---10
1374-- 7 ---07
1375--XTO---23
1376-- - ---34
1377-- 9 ---11
1378-- 0 ---00
1379--XFR---67
1380-- 8 ---10
1381-- 8 ---10
1382--XTO---23
1383-- - ---34
1384-- 9 ---11
1385-- 1 ---01
1386--XFR---67
1387-- 8 ---10
1388-- 9 ---11
1389--XTO---23
1390-- - ---34
1391-- 9 ---11
1392-- 2 ---02
1393--XFR---67
1394-- 8 ---10
1395-- 1 ---01
1396--GTO---44
1397--S/R---77
1398--LBL---51
1399-- G ---15
```

```
1400--XTO---23
1401-- 9 ---11
1402-- 3 ---03
1403--YTO---40
1404-- 9 ---11
1405-- 4 ---04
1406--DN ---25
1407--YTO---40
1408-- 9 ---11
1409-- 5 ---05
1410--XFR---67
1411-- 8 ---10
1412-- 2 ---02
1413--GTO---44
1414--S/R---77
1415--LBL---51
1416-- G ---15
1417--XTO---23
1418-- - ---34
1419-- 9 ---11
1420-- 3 ---03
1421--YTO---40
1422-- - ---34
1423-- 9 ---11
1424-- 4 ---04
1425--DN ---25
1426--YTO---40
1427-- - ---34
1428-- 9 ---11
1429-- 5 ---05
1430--XFR---67
1431-- 9 ---11
1432-- 0 ---00
1433--UP ---27
1434--XFR---67
1435-- 9 ---11
1436-- 1 ---01
1437-- A ---62
1438--XTO---23
1439-- 9 ---11
1440-- 6 ---06
1441--XFR---67
1442-- 9 ---11
1443-- 3 ---03
1444--UP ---27
1445--XFR---67
1446-- 9 ---11
1447-- 4 ---04
1448-- A ---62
1449--UP ---27
1450--XFR---67
1451-- 9 ---11
1452-- 6 ---06
1453--DIV---35
1454--XFR---67
1455-- 6 ---06
1456-- 2 ---02
1457-- * ---36
1458--YTO---40
1459-- 9 ---11
1460-- 7 ---07
1461-- K ---55
1462-- 3 ---03
1463--XFR---67
1464-- 9 ---11
1465-- 2 ---02
1466--UP ---27
1467--XFR---67
1468-- 9 ---11
1469-- 5 ---05
1470-- - ---34
1471--XFR---67
1472-- 9 ---11
1473-- 1 ---01
1474--DIV---35
1475--DN ---25
1476-- L ---72
1477-- O ---71
1478--XTO---23
1479-- 9 ---11
1480-- 8 ---10
1481--XFR---67
1482-- 9 ---11
1483-- 2 ---02
1484--UP ---27
1485--XFR---67
1486-- 9 ---11
1487-- 5 ---05
1488-- - ---34
1489--XFR---67
1490-- 9 ---11
1491-- 0 ---00
1492--DIV---35
1493--DN ---25
1494-- L ---72
1495-- O ---71
1496--XTO---23
1497-- 9 ---11
1498-- 9 ---11
1499--XFR---67
1500-- 9 ---11
1501-- 7 ---07
1502--XFR---67
1503--DIV---35
1504-- 6 ---06
1505-- 2 ---02
1506--XFR---67
1507-- * ---36
1508-- 6 ---06
1509-- 1 ---01
1510--XTO---23
1511-- 1 ---01
1512-- 0 ---00
1513-- 0 ---00
1514--FMT---42
1515-- 4 ---04
1516-- 8 ---10
1517--FMT---42
1518--PI ---56
1519-- A ---13
1520-- E ---60
1521--YTO---40
1522-- E ---60
1523-- N ---73
1524--XTO---23
1525--CNT---47
1526--YTO---40
1527-- C ---61
1528-- A ---62
1529-- L ---72
1530-- E ---60
1531--PNT---45
1532--CLR---20
1533--FMT---42
1534--XFR---67
1535-- 9 ---11
1536-- 7 ---07
1537--FMT---42
1538-- 4 ---04
1539-- 8 ---10
1540--FMT---42
1541-- N ---73
1542-- E ---60
1543--IND---31
1544--CNT---47
1545-- B ---66
1546-- A ---62
1547--YTO---40
1548-- E ---60
1549--PNT---45
1550--CLR---20
1551--FMT---42
1552--UP ---27
1553--XFR---67
1554-- 9 ---11
1555-- 8 ---10
1556--FMT---42
1557-- 4 ---04
1558-- 8 ---10
1559--FMT---42
1560-- O ---71
1561-- M ---70
1562-- E ---60
1563-- G ---15
1564-- A ---62
1565--PNT---45
1566--CLR---20
1567--FMT---42
1568--UP ---27
1569--XFR---67
1570-- 9 ---11
1571-- 9 ---11
1572--FMT---42
1573-- 4 ---04
1574-- 8 ---10
1575--FMT---42
1576--PI ---56
1577-- H ---74
1578-- I ---65
1579--PNT---45
1580--CLR---20
1581--FMT---42
1582--GTO---44
1583--LBL---51
1584-- 2 ---02
1585--LBL---51
1586-- 3 ---03
1587-- 2 ---02
1588-- 0 ---00
1589--UP ---27
1590--UP ---27
1591--STP---41
1592--XTO---23
1593-- B ---14
1594-- 0 ---00
1595--XTO---23
1596-- 0 ---00
1597--GTO---44
1598--S/R---77
1599--LBL---51
```

```
1600-- C ---61
1601--LBL---51
1602--1/X---17
1603-- 1 ---01
1604--XTO---23
1605-- + ---33
1606-- 0 ---00
1607--XFR---67
1608-- 0 ---00
1609--GTO---44
1610--S/R---77
1611--LBL---51
1612-- D ---63
1613-- B ---14
1614--UP ---27
1615--XFR---67
1616-- 0 ---00
1617--X<Y---52
1618--GTO---44
1619--LBL---51
1620--1/X---17
1621--CNT---47
1622--FMT---42
1623-- 4 ---04
1624-- . ---21
1625-- 1 ---01
1626-- 2 ---02
1627-- . ---21
1628-- 3 ---03
1629--GTO---44
1630--S/R---77
1631--LBL---51
1632-- K ---55
1633--XFR---67
1634-- 6 ---06
1635-- 2 ---02
1636--FMT---42
1637-- 4 ---04
1638-- 8 ---10
1639--FMT---42
1640-- B ---66
1641-- A ---62
1642--YTO---40
1643-- E ---60
1644--PNT---45
1645--CLR---20
1646--CLR---20
1647--CLR---20
1648--FMT---42
1649--GTO---44
1650--LBL---51
1651-- 3 ---03
1652--LBL---51
1653-- 4 ---04
1654--FMT---42
1655-- 4 ---04
1656-- . ---21
1657-- 1 ---01
1658-- 0 ---00
1659-- . ---21
1660-- 2 ---02
1661--FMT---42
1662-- 4 ---04
1663-- 8 ---10
1664--FMT---42
1665--CLR---20
1666--CLR---20
1667--YTO---40
1668-- L ---72
1669-- O ---71
1670--PI ---56
1671-- E ---60
1672--CNT---47
1673-- A ---13
1674-- O ---71
1675--1/X---17
1676--XTO---23
1677-- I ---65
1678-- N ---73
1679-- E ---60
1680--CLR---20
1681--CLR---20
1682--FMT---42
1683-- 4 ---04
1684--UP ---27
1685--UP ---27
1686--STP---41
1687--LBL---51
1688--RUP---22
1689--GTO---44
1690--S/R---77
1691--LBL---51
1692-- A ---62
1693--YTO---40
1694-- 9 ---11
1695-- 2 ---02
1696--XFR---67
1697-- 7 ---07
1698-- 8 ---10
1699--XTO---23
1700-- 9 ---11
1701-- 1 ---01
1702--XFR---67
1703-- 7 ---07
1704-- 7 ---07
1705--XTO---23
1706-- 9 ---11
1707-- 0 ---00
1708--GTO---44
1709--S/R---77
1710--LBL---51
1711-- A ---62
1712--YTO---40
1713-- - ---34
1714-- 9 ---11
1715-- 2 ---02
1716--XFR---67
1717-- 7 ---07
1718-- 8 ---10
1719--XTO---23
1720-- - ---34
1721-- 9 ---11
1722-- 1 ---01
1723--XFR---67
1724-- 7 ---07
1725-- 7 ---07
1726--XFR---67
1727-- - ---34
1728-- 9 ---11
1729-- 0 ---00
1730--YE ---24
1731-- 9 ---11
1732-- 1 ---01
1733-- A ---62
1734--YE ---24
1735-- 9 ---11
1736-- 2 ---02
1737--DIV---35
1738-- . ---21
1739-- 0 ---00
1740-- 2 ---02
1741--CHS---32
1742--DIV---35
1743--DN ---25
1744--FMT---42
1745-- 4 ---04
1746-- 8 ---10
1747--FMT---42
1748--PI ---56
1749-- E ---60
1750-- A ---13
1751-- C ---61
1752-- E ---60
1753-- N ---73
1754--XTO---23
1755--CNT---47
1756--YTO---40
1757-- L ---72
1758-- O ---71
1759--PI ---56
1760-- E ---60
1761--PNT---45
1762--CLR---20
1763--CLR---20
1764--FMT---42
1765--UP ---27
1766--UP ---27
1767--PSE---57
1768--PSE---57
1769--PSE---57
1770--PSE---57
1771--PSE---57
1772--PSE---57
1773--PSE---57
1774--PSE---57
1775--PSE---57
1776--PSE---57
1777--PSE---57
1778--PSE---57
1779--GTO---44
1780--LBL---51
1781--RUP---22
1782--LBL---51
1783-- 6 ---06
1784--FMT---42
1785-- 4 ---04
1786-- . ---21
1787-- 9 ---11
1788-- . ---21
1789-- 1 ---01
1790--CNT---47
1791-- 6 ---06
1792--UP ---27
1793--UP ---27
1794--STP---41
1795--LBL---51
1796--IND---31
1797--GTO---44
1798--S/R---77
1799--LBL---51
```

```
1800-- E ---60
1801--XFR---67
1802-- 8 ---10
1803-- 9 ---11
1804--XFR---67
1805-- + ---33
1806-- 6 ---06
1807-- 6 ---06
1808--UP ---27
1809--UP ---27
1810--CNT---47
1811--CNT---47
1812--CNT---47
1813--CNT---47
1814--CNT---47
1815--CNT---47
1816--CNT---47
1817--PSE---57
1818--PSE---57
1819--PSE---57
1820--PSE---57
1821--GTO---44
1822--LBL---51
1823--IND---31
1824--LBL---51
1825-- 5 ---05
1826--GTO---44
1827--S/R---77
1828--LBL---51
1829-- C ---61
1830-- 5 ---05
1831--UP ---27
1832--UP ---27
1833--STP---41
1834--XTO---23
1835-- 6 ---06
1836-- 9 ---11
1837--GTO---44
1838--S/R---77
1839--LBL---51
1840-- D ---63
1841--GTO---44
1842--S/R---77
1843--LBL---51
1844-- E ---60
1845--XFR---67
1846-- 6 ---06
1847-- 9 ---11
1848--GTO---44
1849--S/R---77
1850--LBL---51
1851-- G ---15
1852--DN ---25
1853--YE ---24
1854-- - ---34
1855-- 8 ---10
1856-- 9 ---11
1857--YTO---40
1858-- 6 ---06
1859-- 6 ---06
1860--GTO---44
1861--S/R---77
1862--LBL---51
1863-- K ---55
1864--GTO---44
1865--LBL---51
1866-- 6 ---06
1867--END---46
```

APPENDIX C

FORTRAN IV SOURCE LISTING OF PHOTDIG

```
C PROGRAM 803-K5-G2120(MEMBER PM3G212)  PORTLAND DISTRICT CORPS OF ENGIN
C REDUCTION OF PHOTOGRAMMETRICALLY DIGITIZED THREE-DIMENSIONAL DATA.
C BY FRANK GURSHE, CHIEF PHOTOGRAMMETRY SECTION, JULY 1975
C READS PHOTOGRAMMETRICALL DIGITIZED DATA FROM STANDARD 9-TRACK
C MAGNETIC TAPE WITH 80 DIGIT RECORDS. EACH DIGITIZED POINT REQUIRES
C 40 DIGITS OR HALF OF A COMPLETE RECORD.
C SYSTEM SUBROUTINES 'NORTH','XYDEC','SEARCH'
C
C CALCOMP SUBROUTINES 'SYMBOL','NUMBER','FLINE'
C
C PROGRAM SUBROUTINES 'AZINV','CON3D','ACRE,'MANPLT','ROTRAN','CONVER',
C                    'LIMP','NORSOL','UPDATE','GRDTIC','MAXMIN','ERASMM
C STEREO-MODEL COORDINATES, CONTROL POINT GRID COORDINATES, AND THE
C PARAMETERS OF 3-DIMENSIONAL CONFORMAL TRANSFORMATION SOLUTION.
      COMMON/CCON3D/XMOD(1500),YMOD(1500),ZMOD(1500),XGRID(20),YGRID(20)
     1,ZGRID(20),M(3,3),SCAL,TX,TY,TZ,OMEGA,PHI,KAPPA,NPT,NUMIT,NCODE,
     2 NEQ,NX,NY,NZ,KREP
      REAL*8 XGRID,YGRID,ZGRID,M,SCAL,TX,TY,TZ,OMEGA,PHI,KAPPA
      INTEGER XMOD,YMOD,ZMOD
C PLOTTER LIMITS
      COMMON/CLIMP/XPLIM,YPLIM
C DIGITIZER FIXED DATA VARIABLES
      COMMON/MULT/KST,ID,IDS
      INTEGER*2 KST(1500),ID(1500),IDS(1500)
C ALPHA ARRAY FOR LISTING TAPE RECORDS
      INTEGER*2 DIGREC(80)
C TEMPORARY STEREOMODEL COORDS
      INTEGER XMOD1,XMOD2,YMOD1,YMOD2,ZMOD1,ZMOD2
C MISC VARIABLES FOR COMPUTATION,ETC
      REAL*8 XG,YG,ZG,XG1,YG1,ZG1,XG2,YG2,ZG2,DTEMP,DAZM
      REAL*8 ACRE,ENSCAL,MULTX,MULTY,MULTZ
C DIMENSION MISC VARIABLES, RESIDUALS,
      DIMENSION  MODEL(20),XRES(20),YRES(20),ZRES(20),CONID(20,3)
C CALCULATED GRID VALUES OF CONTROL POINTS
      REAL*8  XCALC(20), YCALC(20), ZCALC(20)
C DIMENSION INTEGER ARRAYS FOR NPD CARD OFFSETS & ELEVATIONS, DP JOB NO.
      INTEGER OFFSET(6),ELEV(6)
      REAL*8 JOB
C VARIABLES FOR TASKS 4 & 5
      REAL*8 LAT,DEP,DPREV,DMD,DAREA,DHOR,DSLOPE
C PLOT ARRAYS FOR 'FLINE' SUBROUTINE
      DIMENSION XARRAY(1500),YARRAY(1500)
      EQUIVALENCE (XMOD(1),XARRAY(1)),(YMOD(1),YARRAY(1))
C 2ND ARRAY FOR CALCOMP SHADING ROUTINE
      DIMENSION XARAY2(4),YARAY2(4)
C
C     SETUP ARRAYS FOR OVERPUNCHING NPD EW CARDS
C
      DIMENSION IOFF(6),IELEV(6),IOVERE(6),IOVERD(6),IOVERD(20)
      DATA IOVERD/1H0,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,2D0, 1HJ,
     1 1HK,1HL,1HM,1HN,1HO,1HP,1HQ,1HR/
C
C
C
```

```
C MISC ALPHA CONSTANTS
      DATA KC/'CARD'/
      DATA KF/'F'/
C PLOTTER LIMITS
      XPLIM=75.0
      YPLIM=48.0
C LIMIT OF NUMBER OF POINTS PER TASK
      LPT=1500
C DEFAULT MULT FACTORS FOR MODEL COORDS(B8)
      MULTX=5.D0
      MULTY=5.D0
      MULTZ=2.5D0
C I/O REFERENCE NUMBERS
      KIN=5
      KOUT=6
      KPUNCH=2
      KPUNEW=7
      KTAPE=8
      KDISC=9
      KDRAW=3
C CALCOMP SYMBOL & LETTER HEIGHTS
      HSYM=.06
      HSYML=.06
      HSECT=.06
      HSTA=.10
      HBNL=.06
      HBNDL=.06
C CONDITION VARIABLES REGARDING STATUS OF INPUT DATA
      KENDI=0
      NEWMOD=1
      KNEXT=0
C MISC. VARIABLES
      RADIAN=57.29578
      PI=3.141593
C INITIALIZE PLOTTER ROUTINES
      CALL PLOTS(DUM,DUM,DUM)
C INITIALIZE 'NWDRAW SUBROUTINE'
      CALL INDRAW(72.0,48.0,4.0,KDRAW)
C-------------------------------------
C READ MAG TAPE. LIST AND WRITE ON DISC
C-------------------------------------
      WRITE (KOUT,130)
      WRITE (KOUT,10)
   10 FORMAT(///   55X,'DIGITIZED DATA LISTING'/55X,22('*'))
      WRITE (KOUT,20)
   20 FORMAT(////  2(5X,'MODEL',1X,'DELETE',1X,'TASK',1X,'SUB',1X,
     1 'POINT-ID',1X,'EVENT',1X,'X-MODEL',1X,'Y-MODEL',1X,'Z-MODEL')/
     2 2(5X,5('-'),1X,6('-'),1X,4('-'),1X,3('-'),1X,8('-'),1X,
     3 5('-'),3(1X,'-------')))
C READ MAG TAPE RECORDS, LISTING AND WRITING ON DISC.
   30 READ (KTAPE,40,ERR=80,END=90) DIGREC
   40 FORMAT(80A1)
   60 WRITE (KOUT,70) DIGREC
   70 FORMAT(2(5X,5A1,4X,A1,4X,2A1,3X,A1,3X,4A1,' ',2A1,2X,4A1,3(1X,7A1)
```

```
     1 ))
      WRITE (KDISC,40) DIGREC
      GO TO 30
   80 WRITE (KOUT,250)
      GO TO 30
   90 END FILE KDISC
C----------------------------
C BEGIN INPUT FOR THIS MODEL
C----------------------------
C REPOSITION DISC TO START OF FILE
      REWIND KDISC
C READ TITLE HEADER CARD FOR THIS MODEL
  100 READ (KIN,110,END=1050) MODEL
  110 FORMAT(20A4)
C READ SECOND HEADER CARD FOR THIS MODEL FOR THE FOLLOWING.
C METRIC CODE,PROPORTIONAL SCALE,CARD INPUT CODE,EARTHWORK CARD JOB ID,
C EARTHWORK CARD TYPE,GRID ORIENTATION, GRID TICK SPACING,& MULT FACTORS
      READ (KIN,120) METRIC,NSCAL,KARD,JOB,KTYPE,GRIDOR,NCOLOR,
     1 NGR1,NGR2,KFEET,MULX,MULY,MULZ
  120 FORMAT(A1,I9,4X,A4,4X,A5,2X,I1,F10.1,I10,18X,I3,1X,I3,A1,1X,3I1)
C CHANGE AXIS MULT. FACTORS IF NON-ZERO.
      IF(MULX.NE.0) MULTX=MULX
      IF(MULY.NE.0) MULTY=MULY
      IF(MULZ.NE.0) MULTZ=MULZ
C MODIFY Z FACTOR FOR GEAR RATIO
      IF(NGR2.NE.0) MULTZ=(MULTZ*NGR1)/NGR2
C MODIFY Z FACTOR IF A10 FEET OPTION IS SET.
      IF(KFEET.EQ.KF) MULTZ=(MULTZ*32)/105
C ASSIGN DEFAULT VALUE TO SCALE OF PLOT.
      IF (NSCAL.EQ.0) NSCAL=600
C PRINT PROGRAM NAME & HEADER DATA
      WRITE (KOUT,130)
  130 FORMAT('1'/////17X,'PHOTOGRAMMETRIC DIGITIZING PROGRAM - PORTLAND
     1DISTRICT CORPS OF ENGINEERS PHOTOGRAMMETRY SECTION'/17X,96('*'))
      WRITE (KOUT,140) MODEL
  140 FORMAT(26X,20A4)
      WRITE (KOUT,150) NSCAL ,GRIDOR
  150 FORMAT(//26X,'SCALE = 1/',I7,6X,'NORTH ANGLE = ',F6.1,'DEGS')
C READ GRID CONTROL POINT CARDS UNTIL END CARD IS ENCOUNTERED.
C 'NCON' WILL BE EQUAL TO NUMBER OF CONTROL POINTS READ.
  160 NCON=1
  170 READ (KIN,180) YGRID(NCON),XGRID(NCON),ZGRID(NCON),
     1    (CONID(NCON,N),N=1,3),KEND
  180 FORMAT(F10.2,5X,F10.2,F10.2,5X,3A4,27X,I1)
      IF (KEND.NE.0) GO TO 200
      NCON=NCON+1
      IF (NCON.EQ.21) WRITE (KOUT,190)
  190 FORMAT(/ 5X,'*DIAGNOSTIC* CONTROL POINT LIMIT HAS BEEN REACHED. NO
     1 MORE WILL BE READ FOR THIS MODEL.')
      IF (NCON.EQ.21) GO TO 200
      GO TO 170
C CONTROL POINT CARDS HAVE BEEN READ FOR THIS MODEL. SUBTRACT END CARD.
  200 NCON=NCON-1
C RESET MODEL ADVANCE CODE TO ZERO, IN CASE IT IS NOW 1
```

```
      KADVAN=0
C-----------------------------------------------------------------------
C DIGITIZED MAG TAPE INPUT ROUTINE. 'NPTS' IS NUMBER OF DIGITIZED STEREO
C MODEL POINTS FOR CURRENT TASK AFTER COMPLETION OF INPUT OF THIS TASK.
C-----------------------------------------------------------------------
  210 NPTS=0
C GO TO APPROPRIATE PART DEPENDING UPON VALUE OF CONDITION CODE 'KNEXT'.
      IF (KNEXT.EQ.1) GO TO 270
      IF (KNEXT.EQ.2) GO TO 300
C READ ONEMAG TAPE 80 DIGIT RECORD FOR 2 DIGITIZED POINTS.
  220 READ (KDISC,230,ERR=240,END=260)
     1                  MOD1,KDEL1,KTAS1,KST1,ID1,IDS1,KEV1,XMOD1,YMOD1,
     2  ZMOD1, MOD2,KDEL2,KTAS2,KST2,ID2,IDS2,KEV2,XMOD2,YMOD2,ZMOD2
  230 FORMAT(2(I5,I1,I2,I1,I4,I2,I4,3I7))
      GO TO 270
C TAPE TRANSMISSION ERROR HAS OCURRED. PRINT DIAGNOSTIC & READ AGAIN.
  240 WRITE (KOUT,250)
  250 FORMAT(/ 5X,'*DIAGNOSTIC* TAPE READ ERROR HAS OCURRED.')
      GO TO 220
C END OF TAPE. SET CONDITION CODE AND TRANSFER TO TASK TESTING ROUTINE.
  260 KEND1=1
      GO TO 310
C
C PROCESS FIRST HALF OF MAG. TAPE RECORD.
C
C CHECK FOR ZERO FILL
  270 IF (MOD1.EQ.0) GO TO 300
C CHECK FOR DELETE CODES
      IF (KDEL1.EQ.1.AND.NPTS.GT.0) NPTS=NPTS-1
      IF (KDEL1.EQ.1) GO TO 300
      IF (KDEL1.EQ.2) KNEXT=2
      IF (KDEL1.EQ.2) GO TO 210
C IF THIS IS THE FIRST POINT FOR THIS MODEL & THE TASK NUMBER IS NOT
C ONE, SKIP THIS MODEL BY SETTING ADVANCE CODE.
      IF (NEWMOD.EQ.1.AND.KTAS1.NE.1) KADVAN=1
      IF (NEWMOD.EQ.1.AND.KTAS1.NE.1) WRITE (KOUT,280) MOD1
  280 FORMAT(/ 5X,'*DIAGNOSTIC* THE FIRST TASK FOR MODEL ',I5,' IS NOT T
     1ASK NUMBER ONE. THIS MODEL WILL BE SKIPPED.')
C IF THIS IS FIRST POINT FOR THIS MODEL, STORE CURRENT MODEL NUMBER, AND
C RESET NEW-MODEL CODE TO ZERO.
      IF (NEWMOD.EQ.1) KURMOD=MOD1
      IF (NEWMOD.EQ.1) NEWMOD=0
C CHECK FOR NEW MODEL. IF NEW RESET NEW-MODEL CODE & TRANSFER TO TASK
C PROCESSING PART OF PROGRAM. SET NEXT CODE ALSO.
      IF (KURMOD.NE.MOD1) NEWMOD=1
      IF (KURMOD.NE.MOD1) KNEXT=1
      IF (KURMOD.NE.MOD1) GO TO 310
C IF THIS IS FIRST POINT FOR A NEW TASK, STORE CURRENT TASK NUMBER.
      IF (NPTS.EQ.0) KURTAS=KTAS1
C CHECK FOR A NEW TASK. IF NEW,TRANSFER TO TASK ROUTINE
      IF (KURTAS.NE.KTAS1) KNEXT=1
      IF (KURTAS.NE.KTAS1) GO TO 310
C CHECK FOR EVENT COUNTER SET BACK TO 1
      IF (KEV1.EQ.1.AND.NPTS.GT.0) KNEXT=1
```

```
      IF (KEV1.EQ.1.AND.NPTS.GT.0) GO TO 310
C CHECK FOR EXCEEDING 500 POINTS IN SAME TASK
      IF (NPTS.EQ.LPT) WRITE (KOUT,290)  KTAS1,MOD1
  290 FORMAT(/ 5X,'*WARNING* THE LIMIT OF POINTS FOR TASK NO.',I2,' OF M
     1ODEL NO.',I5,' HAS BEEN REACHED. A NEW TASK WILL BE STARTED.')
      IF (NPTS.EQ.LPT) KNEXT=1
      IF (NPTS.EQ.LPT) GO TO 310
C INSERT FIRST HALF INTO TASK ARRAYS.(SUBTASK,ID,SUB-ID,& MODEL COORDS.)
      NPTS=NPTS+1
      KST(NPTS)=KST1
      ID(NPTS)=ID1
      IDS(NPTS)=IDS1
      KDEL=KDEL1
C MULTIPLY MODEL COORDINATES BY APPROPRIATE SCALE FACTOR.
      XMOD(NPTS)=XMOD1*MULTX
      YMOD(NPTS)=YMOD1*MULTY
      ZMOD(NPTS)=ZMOD1*MULTZ
C
C PROCESS SECOND HALF OF MAG. TAPE RECORD.
C
C CHECK FOR ZERO FILL. IF ZERO FILL RETURN TO READ NEXT TAPE RECORD
  300 IF (MOD2.EQ.0) GO TO 220
C CHECK FOR DELETE CODES
      IF (KDEL2.EQ.1.AND.NPTS.GT.0) NPTS=NPTS-1
      IF (KDEL2.EQ.1) GO TO 220
      IF (KDEL2.EQ.2) KNEXT=0
      IF (KDEL2.EQ.2) GO TO 210
C CHECK FOR TASK NOT ONE ON FIRST POINT FOR THIS MODEL
      IF (NEWMOD.EQ.1.AND.KTAS2.NE.1) KADVAN=1
      IF (NEWMOD.EQ.1.AND.KTAS1.NE.1) WRITE (KOUT,280) MOD2
C IF FIRST POINT RESET MODEL CODE & SET CURRENT MODEL NUMBER
      IF (NEWMOD.EQ.1) KURMOD=MOD2
      IF (NEWMOD.EQ.1) NEWMOD=0
C CHECK FOR NEW MODEL.
      IF (KURMOD.NE.MOD2) NEWMOD=1
      IF (KURMOD.NE.MOD2) KNEXT=2
      IF (KURMOD.NE.MOD2) GO TO 310
C SET CURRENT TASK IF THIS IS FIRST POINT FOR THIS TASK
      IF (NPTS.EQ.0) KURTAS=KTAS2
C CHECK FOR A NEW TASK
      IF (KURTAS.NE.KTAS2) KNEXT=2
      IF (KURTAS.NE.KTAS2) GO TO 310
C CHECK FOR EVENT COUNTER RESET TO 1
      IF (KEV2.EQ.1.AND.NPTS.GT.0) KNEXT=2
      IF (KEV2.EQ.1.AND.NPTS.GT.0) GO TO 310
C CHECK FOR EXCEEDING 500 POINTS IN ONE TASK
      IF (NPTS.EQ.LPT) WRITE (KOUT,290) KTAS2,MOD2
      IF (NPTS.EQ.LPT) KNEXT=2
      IF (NPTS.EQ.LPT) GO TO 310
C INSERT 2ND HALF OF TAPE RECORD INTO TASK ARRAYS
      NPTS=NPTS+1
      KST(NPTS)=KST2
      ID(NPTS)=ID2
      IDS(NPTS)=IDS2
```

```
      KDEL=KDEL2
C MULTIPLY MODEL COORDINATES BY APPROPRIATE SCALE FACTOR.
      XMOD(NPTS)=XMOD2*MULTX
      YMOD(NPTS)=YMOD2*MULTY
      ZMOD(NPTS)=ZMOD2*MULTZ
C RETURN TO READ THE NEXT TAPE RECORD.(2 DIGITIZED POINTS)
      GO TO 220
C----------------------
C TASK SELECTION ROUTINE
C----------------------
C SKIP TASKS IF MODEL ADVANCE CODE IS SET TO ONE.
  310 IF (KADVAN.EQ.1) GO TO 330
C RETURN TO PEN 1 UNLESS DELETE CODE IS 5,6, OR 7 FOR APPROPRIATE PEN.
C IF NCOLOR=1 OVER-RIDE DELETE CODE AND RETURN TO PEN 1.
      NPEN=1
      IF(KDEL.EQ.5) NPEN=2
      IF(KDEL.EQ.6) NPEN=3
      IF(KDEL.EQ.7) NPEN=4
      IF(NCOLOR.EQ.1) NPEN=1
      CALL NEWPEN(NPEN)
C CHECK TASK CODE AND TRANSFER TO APPROPRIATE TASK ROUTINE.
      IF (KURTAS.EQ.1) GO TO 340
      IF (KURTAS.EQ.2) GO TO 600
      IF (KURTAS.EQ.3) GO TO 660
      IF (KURTAS.EQ.4) GO TO 850
      IF (KURTAS.EQ.5) GO TO 850
C IF PRESIMBA TASKS ENCOUNTERED SKIP WITHOUT DIAGNOSTIC
      IF(KURTAS.EQ.91) GO TO 330
      IF(KURTAS.EQ.92) GO TO 330
C NO VALID TASK HAS BEEN FOUND. WRITE DIAGNOSTIC.
      WRITE (KOUT,320) KURTAS,KURMOD
  320 FORMAT(/ 5X,'*DIAGNOSTIC* TASK NUMBER',I2,' OF MODEL NO.',I5,' IS
     1 NOT A VALID TASK. CONSULT OLEDA FOR CORRECT NUMBER.')
C CURRENT TASK HAS BEEN EXECUTED
C CHECK FOR END OF TAPE CODE SET TO ONE.
  330 IF (KENDT.EQ.1) GO TO 1050
C IF NEW MODEL CODE IS SET RETURN TO READ 2 HEADER CARDS & GRID CONTROL
C CARDS FOR ANOTHER MODEL. OTHERWISE READ ANOTHER SET OF MAG TAPE
C RECORDS FOR THE NEXT TASK.
      IF (NEWMOD.EQ.1) GO TO 100
      IF (NEWMOD.EQ.0) GO TO 210
C-----------------------
C TASK PORTION OF PROGRAM
C-----------------------
C
C---------------------------------------
C TASK NUMBER 1 - PROCESS CONTROL POINTS
C---------------------------------------
C WRITE TASK TITLE & MODEL NUMBER
  340 WRITE (KOUT,350)
  350 FORMAT(////55X,'CONTROL POINTS'/55X,14('*'))
      WRITE (KOUT,360) KURMOD
  360 FORMAT(55X,'MODEL NUMBER',I6)
C IF MORE THAN ONE OBSERVED CONTROL POINT COMPUTE MEAN.
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```
      NOBS=KST(1)
      CALL MULTOB(XMOD,YMOD,ZMOD,NPTS,NOBS)
C CHECK TO SEE IF NUMBER OF CONTROL CARDS MATCHES NO. OF DIGITIZED PTS.
  370 IF (NCON.NE.NPTS) WRITE (KOUT,380) NCON,NPTS
  380 FORMAT(/5X,'*WARNING*',I3,' CONTROL POINTS READ IN ON CARDS, BUT',
     1 I5,' CONTROL POINTS DIGITIZED. THE SMALLER NUMBER WILL BE USED.')
      NPT=NCON
      IF (NPTS.LT.NCON) NPT=NPTS
C SET CODE INDICATING FIRST PASS THROUGH CON3D FOR THIS MODEL.
      KREP=0
C SOLVE FOR TRANSFORMATION PARAMETERS
  390 CALL CON3D
C CHECK FOR ERROR CONDITIONS. IF PRESENT, SET MODEL ADVANCE CODE.
      IF (NCODE.NE.2) GO TO 410
      WRITE (KOUT,400)
  400 FORMAT(/5X,'DIAGNOSTIC* NOT ENOUGH CONTROL FOR SOLUTION. THIS MODE
     1L WILL BE SKIPPED.')
      GO TO 450
  410 IF (NCODE.NE.3) GO TO 430
      WRITE (KOUT,420)
  420 FORMAT(/5X,'*DIAGNOSTIC* LIMIT OF ITERATIONS HAS BEEN REACHED WITH
     1OUT CONVERGENCE. THIS MODEL WILL BE SKIPPED.')
      GO TO 450
  430 IF (NCODE.NE.4) GO TO 470
      WRITE (KOUT,440)
  440 FORMAT(/5X,'*DIAGNOSTIC* DIVISION BY ZERO HAS OCURRED IN THE SOLUT
     1ION OF THE NORMAL EQUATIONS. THIS MODEL WILL BE SKIPPED.')
C INITIALIZE RESIDUALS TO ZERO FOR NEAT PRINTOUT
  450 DO 460 N=1,NPT
      XRES(N)=0.0
      YRES(N)=0.0
  460 ZRES(N)=0.0
C SET MODEL ADVANCE CODE & TRANSFER TO PRINT PORTION OF ROUTINE
      KADVAN=1
      GO TO 490
C INITIALIZE SUM OF THE SQUARES VARIABLES TO ZEROS
  470 SUMX2=0.0
      SUMY2=0.0
      SUMZ2=0.0
C CALCULATE GRID COORDS, RESIDUALS, AND SUM OF SQUARES OF THE RESIDUALS.
      DO 480 N=1,NPT
C CONVERT MODEL TO GRID COORDS.
      CALL CONVER(XMOD(N),YMOD(N),ZMOD(N),XCALC(N),YCALC(N),ZCALC(N))
C CALCULATE RESIDUALS OR SET TO ZERO IF THERE WAS NO GRID VALUE
C ORIGINALLY  READ IN.
      XRES(N)=XCALC(N)-XGRID(N)
      IF (XGRID(N).EQ.0.D0) XRES(N)=0.0
      YRES(N)=YCALC(N)-YGRID(N)
      IF (YGRID(N).EQ.0.D0) YRES(N)=0.0
      ZRES(N)=ZCALC(N)-ZGRID(N)
      IF (ZGRID(N).EQ.0.D0) ZRES(N)=0.0
C UPDATE SUM OF THE SQUARE OF THE RESIDUALS
      SUMX2=SUMX2+XRES(N)**2
      SUMY2=SUMY2+YRES(N)**2
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      SUMZ2=SUMZ2+ZRES(N)**2
  480 CONTINUE
C CALCULATE STANDARD DEVIATIONS, DIVIDE SUMS BY N-1 AND TAKE SQUARE-ROOT
      SIGMAX=SQRT(SUMX2/NX)
      SIGMAY=SQRT(SUMY2/NY)
      SIGMAZ=SQRT(SUMZ2/NZ)
C CALCULATE 3-SIGMA(99 PERCENT ERROR)
      SIG3X=3*SIGMAX
      SIG3Y=3*SIGMAY
      SIG3Z=3*SIGMAZ
C PRINT COLUMN HEADINGS
  490 WRITE (KOUT,500)
  500 FORMAT(///   1X,'SEQUENCE NO.',2X,'X-MODEL',2X,'Y-MODEL',2X,
     1 'Z-MODEL',2X,
     2 'X-GRID(EAST)',2X,'Y-GRID(NORTH)',2X,'Z-GRID(ELEV.)')
      WRITE (KOUT,510)
  510 FORMAT('+',85X,'X-RESIDUAL',2X,'Y-RESIDUAL',2X,'Z-RESIDUAL',
     1 2X,'POINT I.D.')
      WRITE (KOUT,520)
  520 FORMAT(1X,12('-'),2X,7('-'),2X,7('-'),2X,7('-'),2X,
     1           12('-'),2X,13('-'),2X,13('-'))
      WRITE (KOUT,530)
  530 FORMAT('+',85X,10('-'),2X,10('-'),2X,10('-'),2X,10('-'))
C PRINT MODEL COORDINATES, ORIGINAL GRID COORDINATES, & RESIDUALS
      DO 540 N=1,NPT
      WRITE(KOUT,531) N,XMOD(N),YMOD(N),ZMOD(N),(CUNID(N,K),K=1,3)
  531 FORMAT(1X,I11,3(2X,I7),82X,3A4)
      IF(XGRID(N).NE.0.D0) WRITE(KOUT,532) XGRID(N),XRES(N)
  532 FORMAT('+',40X,F12.2,32X,F10.2,38X)
      IF(YGRID(N).NE.0.D0) WRITE(KOUT,533) YGRID(N),YRES(N)
  533 FORMAT('+',54X,F13.2,29X,F10.2,26X)
      IF(ZGRID(N).NE.0.D0) WRITE(KOUT,534) ZGRID(N),ZRES(N)
  534 FORMAT('+',69X,F13.2,26X,F10.2,14X)
C PRINT CALCULATED COORD. IF NO ORIGINAL GRID VALUE
      IF(KADVAN.EQ.1) GO TO 540
      IF(XGRID(N).EQ.0.D0) WRITE(KOUT,532) XCALC(N)
      IF(YGRID(N).EQ.0.D0) WRITE(KOUT,533) YCALC(N)
      IF(ZGRID(N).EQ.0.D0) WRITE(KOUT,534) ZCALC(N)
  540 CONTINUE
C IF MODEL AVANCE CODE IS SET TRANSFER TO END OF TASK SECTION OF PROGRAM
      IF (KADVAN.EQ.1) GO TO 330
C PRINT STANDARD DEVIATIONS(SIGMA),NO. ITERATIONS, & DEGREES OF FREEDOM
      NDF=NEQ-4
      WRITE (KOUT,550) SIGMAX,SIGMAY,SIGMAZ,NUMIT,NDF
  550 FORMAT(///1X,'STANDARD DEVIATION OF RESIDUALS.', 5X,'X = ',F6.2,
     1  5X,'Y = ',F6.2, 5X,'Z= ',F6.2 /
     2 1X,'NUMBER OF ITERATIONS REQUIRED FOR SOLUTION = ',I2 /
     3 1X,'DEGREES OF FREEDOM = ',I2)
C CALCULATE AND PRINT MODEL SCALE AND OMEGA, PHI CORRECTIONS FOR B8
      SPROP=SCAL *.3048/1.0E-6
      B8OMEG=OMEGA*RADIAN/.9
      B8PHI=-PHI*RADIAN/.9
      WRITE (KOUT,560) SPROP,B8OMEG,B8PHI
  560 FORMAT(1X,'MODEL SCALE = 1/',F12.4/
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     1        1X,'OMEGA(68) = ',F5.2/
     2        1X,'PHI(68) = ',F5.2)
C WRITE MESSAGE IF MORE THAN 1 OBSERVATION OF CONTROL POINTS
      IF(NOBS.GT.1) WRITE(KOUT,565) NOBS
  565 FORMAT(1X,'EACH POINT WAS DIGITIZED',I2,' TIMES.')
C LOOK FOR RESIDUALS GREATER THAN 3XSIGMA(99 PERCENT ERROR)
C IF FOUND SET CORRESPONDING ORIGINAL GRID VALUE TO ZERO FOR POSSIBLE
C RECOMPUTATION OF PARAMETERS.
      NUMGT=0
      DO 570 N=1,NPT
      IF (ABS(XRES(N)).GT.SIG3X) NUMGT=NUMGT+1
      IF (ABS(XRES(N)).GT.SIG3X) XGRID(N)=0.D0
      IF (ABS(YRES(N)).GT.SIG3Y) NUMGT=NUMGT+1
      IF (ABS(YRES(N)).GT.SIG3Y) YGRID(N)=0.D0
      IF (ABS(ZRES(N)).GT.SIG3Z) NUMGT=NUMGT+1
      IF (ABS(ZRES(N)).GT.SIG3Z) ZGRID(N)=0.D0
  570 CONTINUE
C RETURN FOR ANOTHER SOLUTION OF PARAMETERS IF LARGE RESIDUALS WERE
C FOUND AND IF THERE ARE ENOUGH EQUATIONS FOR SOLUTION.
      NDF=NDF-NUMGT
      IF (NDF.GE.0.AND.NUMGT.GT.0) WRITE (KOUT,580) NUMGT
      IF (NDF.GE.0.AND.NUMGT.GT.0) KREP=1
      IF (NDF.GE.0.AND.NUMGT.GT.0) GO TO 390
  580 FORMAT(/5X,'*NOTE*',I2,' PARAMETERS HAVE RESIDUALS LARGER THAN THE
     1 THE 99 PERCENT ERROR. ANOTHER SOLUTION WILL BE TRIED WITHOUT THEM
     2.')
C START NEW PAGE FOR THE REST OF THE TASKS
      WRITE(KOUT,585)
  585 FORMAT('1')
C PREPARE TO PLOT GRID & CONTROL POINTS FOR THIS MODEL
C SUBSTITE CALCULATED X&Y COORDS. FOR INPUT GRID COORDS.
      DO 590 N=1,NPT
      XGRID(N)=XCALC(N)
  590 YGRID(N)=YCALC(N)
C PLOT GRID & CONTROL POINTS
      CALL MANPLT(NPT, NSCAL,GRIDOR,MODEL,METRIC)
C WRITE PEN NUMBER
      WRITE(KOUT,595) NPEN
  595 FORMAT(55X,'PEN NUMBER',I2)
C RETURN TO END OF TASK SECTION
      GO TO 330
C-----------------------------------------------------------------
C TASK NUMBER 2 - ESTABLISH GRID COORDS & PLOT FOR RANDOM POINTS.
C-----------------------------------------------------------------
C WRITE HEADING FOR TASK
  600 WRITE (KOUT,610)
  610 FORMAT(/////55X,'RANDOM POINTS'/55X,13('*'))
      WRITE (KOUT,360) KURMOD
C WRITE COLUMN HEADINGS
      WRITE (KOUT,500)
      WRITE (KOUT,620)
  620 FORMAT('+',85X,'POINT I.D.',2X,'PLOT SYMBOL')
      WRITE (KOUT,520)
      WRITE (KOUT,630)
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  630 FORMAT('+',85X,10('-'),2X,11('-'))
C NEW SEARCH RECORD
      CALL PLOT(0.,0.,-3)
C AVERAGE MULTIPLE READINGS
      NOBS=KST(1)
      CALL MULTOB(XMOD,YMOD,ZMOD,NPTS,NOBS)
C PROCESS EACH POINT
      DO 650 N=1,NPTS
C CONVERT MODEL COORDS TO GRID COORDS
      CALL CONVER(XMOD(N),YMOD(N),ZMOD(N),XG,YG,ZG)
C WRITE SEQUENCE NUMBER, COORDS, POINT I.D., & PLOT SYMBOL NUMBER
      WRITE (KOUT,640) N,XMOD(N),YMOD(N),ZMOD(N),XG,YG,ZG,ID(N),IDS(N)
  640 FORMAT(1X,I12,3(2X,I7),2X,F12.2,2(2X,F13.2),2X,I10,2X,I11)
C PUNCH GRID CONTROL CARDS.
      IF(ID(N).EQ.0) WRITE(KPUNCH,645) YG,XG,ZG
      IF(ID(N).NE.0) WRITE(KPUNCH,645) YG,XG,ZG,ID(N)
  645 FORMAT(F10.2,5X,2F10.2,5X,I4)
C CONVERT GRID COORD. TO PLOT COORD.
      CALL ROTRAN(XG,YG,XPLOT,YPLOT,1)
C CHECK FOR BEING WITHIN PLOTTER LIMITS. SKIP PLOTTING IF NOT WITHIN.
      IF (LIMP(XPLOT,YPLOT).EQ.1) GO TO 650
C IF SUB ID IS 20 PLOT DECIMAL ELEVATION INSTEAD OF CALCOMP SYSMBOL
      IF (IDS(N).EQ.20) FPN=ZG
      IF (IDS(N).EQ.20) CALL XYDEC(XPLOT,YPLOT,HSYM,FPN,0.,1)
      IF (IDS(N).EQ.20) GO TO 650
C PLOT SYMBOL WITH SYMBOL CODE INPUT ON MAG. TAPE
      NSYM=IDS(N)
      CALL SYMBOL(XPLOT,YPLOT,HSYM,NSYM  ,0.,-1)
C ANNOTATE PLOTTED SYMBOL WITH ID # IF NOT ZERO.
      IF(ID(N).EQ.0) GO TO 650
      FPN=ID(N)
      CALL NUMBER(999.,999.,HSYML,FPN,0.,-1)
  650 CONTINUE
C WRITE MESSAGE FOR MULTIPLE OBSERVATIONS OF POINTS
      IF(NOBS.GT.1) WRITE(KOUT,565) NOBS
C WRITE SEARCH RECORD INFORMATION
      CALL SEARCH(NSR)
      WRITE (KOUT,660) KURMOD
  660 FORMAT(//55X,'RANDOM POINTS HAVE BEEN PLOTTED FOR MODEL NO. ',I5/
     1       55X,51('-'))
      WRITE (KOUT,670) NSR
  670 FORMAT(55X,'SEARCH RECORD NUMBER',I4)
C WRITE PEN NUMBER
      WRITE(KOUT,595) NPEN
C RETURN TO END OF TASK SECTION.
      GO TO 330
C-----------------------------------------------------------
C TASK NUMBER 3 - CROSS SECTIONS WITH NPD EARTHWORK CARDS
C-----------------------------------------------------------
C WRITE HEADING FOR TASK, MODEL NO., AND STATION.
  680 WRITE (KOUT,690)
  690 FORMAT(/////55X,'CROSS SECTION'/55X,13('*'))
      WRITE (KOUT,360) KURMOD
      WRITE (KOUT,700) ID(1),IDS(1)
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  700 FORMAT(55X,'STATION ',I4,'+',I2)
C CALCULATE AZMUTH OF X-SECTION
      CALL CONVER(XMOD(1),YMOD(1),ZMOD(1),XG1,YG1,ZG1)
      CALL CONVER(XMOD(NPTS),YMOD(NPTS),ZMOD(NPTS),XG2,YG2,ZG2)
      CALL AZINV(YG1,XG1,YG2,XG2,DAZM,DTEMP)
      AZMXS=DAZM
C CALCULATE PLOT ANGLES FOR ELEVATION NUMBERS & FOR STATION ANNOTATION.
      ANGXS=GRIDOR+90.-DAZM*RADIAN
      ANGBL=ANGXS+90.
C BE SURE PLOT ANGLE OF ELEVATION POINT  IS NOT UPSIDE DOWN
      ANGEL= ANGBL
      IF( COS(ANGEL/RADIAN).LT.0.00) ANGEL=ANGEL+180.0
C SEARCH FOR DIGITIZED REFERENCE POINT. IF NOT FOUND, ASSUME THAT THE
C FIRST POINT IS THE REFERENCE POINT.
      NREF=1
      DO 710 N=1,NPTS
      IF (KSI(N).NE.0) NREF=N
  710 CONTINUE
C CONVERT MODEL COORDS TO GRID
      CALL CONVER(XMOD(NREF),YMOD(NREF),ZMOD(NREF),XG1,YG1,ZG1)
C WRITE COLUMN HEADINGS
      WRITE (KOUT,500)
      WRITE (KOUT,720)
  720 FORMAT('+',85X,'OFFSET DISTANCE')
      WRITE (KOUT,520)
      WRITE (KOUT,730)
  730 FORMAT('+',85X,15('-'))
C NEW SEARCH RECORD
      CALL PLOT(0.,0.,-3)
C SET TO ZERO THE VARIABLE TO BE USED AS THE SUBCRIPT OF THE DIGITIZED
C POINTS ARRAY. DO THE SAME FOR THE CHANGE OF AZMUTH CODE.
      NDIG=0
      KCHAN=0
C PROCESS EACH DIGITIZED POINT. 'N'= THE SEQUENCE OF THE CROSS SECTION
C POINTS AFTER ADJUSTMENT OF THE REFERENCE POINT.
      DO 830  N=1,NPTS
      NDIG=NDIG+1
C IF THE REFERENCE POINT IS ENCOUNTERED SKIP UNTIL CHANGE OF AZMUTH
C IS ENCOUNTERED
      IF (NDIG.EQ.NREF) NDIG=NDIG+1
C CALCULATE OFFSET DISTANCE & AZMUTH FROM REFERENCE POINT
      CALL CONVER(XMOD(NDIG),YMOD(NDIG),ZMOD(NDIG),XG,YG,ZG)
      CALL AZINV(YG1,XG1,YG,XG,DAZM,DTEMP)
C CHECK TO SEE IF AZMUTH IS POSITIVE OR NEGATIVE RELATIVE TO AZMUTH
C OF X-SECTION LINE. SET CODE 'KPOS' TO INDICATE WHAT SIDE POINT IS ON.
      CHECK=RADIAN*DABS(DAZM-AZMXS)
      KPOS=-1
      IF (CHECK.LT.90.0.OR.CHECK.GT.270.0) KPOS=1
C CHECK FOR FIRST POSITIVE OFFSET DISTANCE. TRANSFER TO SPECIAL ROUTINE
C FOR INSERTION OF CENTER POINT.
      IF (KPOS.EQ.1.AND.KCHAN.EQ.0) GO TO 750
C ASSIGN THE APPROPRIATE SIGN TO OFFSET DISTANCE
      DTEMP=DTEMP*KPOS
C PRINT SEQUENCE NUMBER,MODEL COORDS, GRID COORDS, AND OFFSET DIST.
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      WRITE (KOUT,740) N,XMOD(NDIG),YMOD(NDIG),ZMOD(NDIG),XG,YG,ZG,DTEMP
  740 FORMAT(1X,I12,3(2X, I7),2X,F12.2,2(2X,F13.2),2X,F15.2)
      GO TO 760
C
C INSERT DIGITIZED REFERENCE POINT, BEFORE CONTINUING WITH + OFFSETS.
C DECREASE DIGITIZED POINT COUNTER BY ONE SO THE NEXT POINT NOT SKIPPED.
  750 NDIG=NDIG-1
C SET CHANGE OF OFFSET DIRECTION FLAG.
      KCHAN=1
C SET OFFSET DISTANCE TO ZERO AND DEFINE REGULAR GRID VARIABLES
      DTEMP=0.
      XG=XG1
      YG=YG1
      ZG=ZG1
C PRINT SEQ NO.,MODEL COORDS,ETC.
      WRITE (KOUT,740) N,XMOD(NREF),YMOD(NREF),ZMOD(NREF),XG1,YG1,ZG1,
     1                 DTEMP
C
C NPD EARTHWORK CARDS ROUTINE
C
C STORE ELEVATION & OFFSET DIST IN INTEGER ARRAYS
  760 NPD=MOD(N,6)
      IF (NPD.EQ.0) NPD=6
      IF(DTEMP.EQ.0.0D0) DTEMP=.001D0
      IF(ZG.EQ.0.D0) ZG=.001D0
      ELEV(NPD)=(DABS(ZG)+.05)*10*DABS(ZG)/ZG
      OFFSET(NPD)=(DABS(DTEMP)+.05)*10*DABS(DTEMP)/DTEMP
C CHECK OFFSET DISTANCES FOR BEING EQUAL OR NOT IN SEQUENCE. SKIP FIRST.
      IF (N.EQ.1) GO TO 780
      IF ((OFFSET(NPD)-LASOFF).LE.0) WRITE (KOUT,770)
  770 FORMAT(1X,'*WARNING* THE PREVIOUS TWO POINTS ARE NOT IN ASCENDING
     1ORDER.')
  780 LASOFF=OFFSET(NPD)
C MAKE NEGATIVE OFFSET DISTANCES POSITIVE FOR THE NPD EARTHWORK CARD
C     OFFSET(NPD)=IABS(OFFSET(NPD))
C IF THIS IS 6TH POINT OF LAST POINT PUNCH NPD EARTHWORK CARD. OTHERWISE
C TRANSFER TO PLOT ROUTINE.
      IF (NPD.NE.6.AND.N.NE.NPTS) GO TO 800
C CALCULATE CARD SEQUENCE NUMBER
      NCARD=N/6.0+.9
C PUNCH NPD CARD
C     FIXUP FOR OVERPUNCHING MINUSES,DICKINSON, 31AUG78
C
      DO 788 L=1,NPD
      IELEV(L)=ELEV(L)/10.0+0.01
      IOVERE(L)=IABS(ELEV(L))-IABS(IELEV(L))*10+0.01
      IOVERE(L)=IOVERE(L)+1
      IF(ELEV(L).GE.0) GOTO 782
      IELEV(L)=-IELEV(L)
        IOVERE(L)=IOVERE(L)+10
782   IOVERE(L)=IOVERD(IOVERE(L))
C
C     NOW FIXUP OFFSET(DISTANCE)
      IOFF(L)=OFFSET(L)/10.0+0.01
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      IOVERO(L)=IABS(OFFSET(L))-IABS(IOFF(L))*10 +0.01
      IOVERO(L)=IOVERO(L)+1
      IF(OFFSET(L).GE.0) GOTO 788
      IOVERO(L)=IOVERO(L)+10
      IOFF(L)=-IOFF(L)
  788 IOVERO(L)=IOVERD(IOVERO(L))
C
C     NOW PUNCH OUT NPD EW CARD
C
      WRITE(KPUNEW,790) JOB,KTYPE,ID(1),IDS(1),NCARD,
     1(IELEV(K),IOVERE(K),IOFF(K),IOVERO(K),K=1,NPD)
  790 FORMAT(A5,I1,I4,I2,'000000',I2,12(I4,A1))
CC
C     WRITE (KPUNEW,790) JOB,KTYPE,ID(1),IDS(1),NCARD,
C    1                   (ELEV(K),OFFSET(K),K=1,NPD)
C 790 FORMAT(A5,I1,I4,I2,'000000',I2,12I5)
  800 FPN=ZG
      CALL ROTRAN(XG,YG,XPLOT,YPLOT,1)
C PLOT ONLY SMALL DOT IF THIS POINT IS TOO CLOSE TO THE LAST.
      IF (N.EQ.1) GO TO 810
      CHECK= ABS((LASOFP-OFFSET(NPD))*1.2/NSCAL)
      IF (CHECK.LT.HSECT) CALL SYMBOL(XPLOT,YPLOT,.01,13,ANGXS,-1)
      IF (CHECK.LT.HSECT) GO TO 820
C PLOT ELEVATION POINT
  810 CALL XYDEC(XPLOT,YPLOT,HSECT,FPN,ANGEL,1)
C STORE LAST OFFSET DISTANCE PLOTTED WITH DECIMAL
      LASOFP=OFFSET(NPD)
C PLOT STATION ON LAST POINT
  820 IF (N.LT.NPTS) GO TO 830
      CALL SYMBOL(999.,999.,.10,' ',ANGXS,1)
      FPN=ID(1)
      CALL NUMBER(999.,999.,.10,FPN,ANGXS,-1)
      CALL SYMBOL(999.,999.,.10,'+',ANGXS,1)
      FPN=IDS(1)
      CALL NUMBER(999.,999.,.10,FPN,ANGXS,-1)
C END OF POINT PROCESSING FOR THIS X-SECTION.
  830 CONTINUE
C WRITE SEARCH RECORD INFORMATION
      CALL SEARCH(NSR)
      WRITE (KOUT,840) NPTS,ID(1),IDS(1)
  840 FORMAT(//  55X,I3,' ELEVATION POINTS HAVE BEEN PLOTTED FOR X-SECTI
     1ON ',I4,'+',I2/ 55X,60('-'))
      WRITE (KOUT,670) NSR
C WRITE PEN NUMBER
      WRITE(KOUT,595) NPEN
C RETURN TO END-OF-TASK ROUTINE.
      GO TO 330
C-----------------------------------------------------------
C TASK NUMBERS 4 AND 5 -  BOUNDED AREAS & LINEAL FEATURES
C-----------------------------------------------------------
C WRITE TASK TITLE, MODEL NUMBER, & AREA ID
  850 IF (KURTAS.EQ.4) WRITE (KOUT,860)
  860 FORMAT(//// 55X,'BOUNDED AREA'/55X,12('*'))
      IF (KURTAS.EQ.5) WRITE (KOUT,870)
```

```
870 FORMAT(///// 55X,'LINEAL FEATURE'/55X,14('*'))
    WRITE (KOUT,360) KURMOD
    WRITE (KOUT,880) ID(1),KST(1)
880 FORMAT(55X,     'IDENTIFICATION NUMBER ',I4/55X,'SUB-TASK NUMBER '
   1,I1)
C WRITE COLUMN HEADINGS
    WRITE (KOUT,500)
    WRITE (KOUT,890)
890 FORMAT('+',85X,'PLOT SYMBOL',2X,'DISTANCE(HORIZ)',2X,
   1 'DISTANCE(SLOPE)')
    WRITE (KOUT,520)
    WRITE (KOUT,900)
900 FORMAT('+',85X,11('-'),2(2X,15('-')))
C INITIALIZE HORIZONTAL & SLOPE DISTANCE ACCUMULATORS
    DHOR=0.D0
    DSLOPE=0.D0
C INITIALIZE  AREA VARIABLES AND AVERAGE PLOT COORD VARIABLES
    DPREV=0.D0
    DMD=0.D0
    DAREA=0.D0
    XPLOTM=0.
    YPLOTM=0.
C CONVERT MODEL COORDS OF FIRST POINT TO GRID COORDS.
    CALL CONVER(XMOD(1),YMOD(1),ZMOD(1),XG1,YG1,ZG1)
C NEW SEARCH RECORD
    CALL PLOT(0.,0.,-3)
C SET MODEL COORDS OF  NPTS+1 EQUAL TO FIRST POINT
    XMOD(NPTS+1)=XMOD(1)
    YMOD(NPTS+1)=YMOD(1)
    ZMOD(NPTS+1)=ZMOD(1)
C FOR EACH SEGMENT, CALCULATE AREA, HORIZ. AND SLOPE DIST. PRINT COORDS&
C CALCULATE MEAN PLOT COORDS FOR CENTERING ID NUMBER.
    DO 950  N=1,NPTS
C PRINT MODEL & GRID COORDS & PLOT SYMBOL OF FIRST POINT OF THIS SEGMENT
    WRITE (KOUT,910) N,XMOD(N),YMOD(N),ZMOD(N),XG1,YG1,ZG1,IDS(N),
   1                 DHOR,DSLOPE
910 FORMAT(1X,I12,3(2X,I7),2X,F12.2,2(2X,F13.2),2X,I11,2(2X,F14.2))
C CONVERT 2ND POINT OF THIS SEGMENT TO GRID COORDS.
    CALL CONVER(XMOD(N+1),YMOD(N+1),ZMOD(N+1),XG2,YG2,ZG2)
C CALCULATE DMD ACREAGE FOR THIS SEGMENT
    LAT=YG2-YG1
    DEP=XG2-XG1
    DMD=DMD+DEP+DPREV
    DAREA=DAREA+DMD*LAT
    DPREV=DEP
C FILL PLOT ARRAY WITH PLOT COORDS OF FIRST POINT OF THIS SEGMENT
    CALL ROTRAN(XG1,YG1,XARRAY(N),YARRAY(N),1)
C UPDATE SUM OF MEAN PLOT COORDS.
    XPLOTM=XPLOTM+XARRAY(N)
    YPLOTM=YPLOTM+YARRAY(N)
C PLOT ELEVATION OF FIRST POINT IF PLOT CODE=20
920 IF (IDS(N).NE.20) GO TO 930
    FPN=ZG1
    CALL XYDEC(XARRAY(N),YARRAY(N),HBND,FPN,0.,1)
```

```
C ACCUMULATE HORIZONTAL & SLOPE DISTANCE. SKIP IF LAST SEGMENT & TASK=5
  930 IF (KURTAS.EQ.5.AND.N.EQ.NPTS) GO TO 940
      CALL AZINV(YG1,XG1,YG2,XG2,DAZM,DTEMP)
      DHOR=DHOR+DTEMP
      CALL AZINV(ZG1,0.D0,ZG2,DTEMP,DAZM,DEP)
      DSLOPE=DSLOPE+DEP
C REPLACE FIRST GRID POINT WITH SECOND FOR THE NEXT SEGMENT
  940 XG1=XG2
      YG1=YG2
      ZG1=ZG2
C RETURN FOR THE NEXT SEGMENT
  950 CONTINUE
C IF TASK=4 ADD FIRST POINT TO LAST ELEMENT OF PLOT ARRAY FOR CLOSURE.
      IF (KURTAS.EQ.4) NPTS=NPTS+1
      IF (KURTAS.EQ.4) CALL ROTRAN(XG2,YG2,XARRAY(NPTS),YARRAY(NPTS),1)
C INITIALIZE NPTS+1 & NPTS+2 ELEMENTS OF PLOT ARRAY AS REQUIRED BY FLINE
      XARRAY(NPTS+1)=0.0
      YARRAY(NPTS+1)=0.0
      XARRAY(NPTS+2)=1.0
      YARRAY(NPTS+2)=1.0
C SET-UP OPTIONS FOR 'FLINE' PLOT SUBROUTINE.
      NFLN=NPTS
C SMOOTH CURVE
      IF (KST(1).EQ.1) NFLN=-NPTS
      IF (KST(1).EQ.4) NFLN=-NPTS
C NO CONNECTING LINES
      LINTYP=1
      IF (KST(1).EQ.2.AND.(IDS(1).EQ.20.OR.IDS(1).EQ.21)) GO TO 955
      IF (KST(1).EQ.5.AND.(IDS(1).EQ.20.OR.IDS(1).EQ.21)) GO TO 955
      IF (KST(1).EQ.2) LINTYP=-1
      IF (KST(1).EQ.5) LINTYP=-1
C NO SYMBOLS
      IF (IDS(1).EQ.21.OR.IDS(1).EQ.20) LINTYP=0
C PLOT BOUNDARY OR LINEAL FEATURE
      NSYM=IDS(1)
      CALL FLINE(XARRAY,YARRAY,NFLN,1,LINTYP,NSYM)
C CHECK FOR SHADING ROUTINE. SHADE IF REQUESTED.
  955 IF(KST(1).LT.3.OR.KST(1).GT.5) GO TO 960
      XARAY2(3)=0.0
      XARAY2(4)=1.0
      YARAY2(3)=0.0
      YARAY2(4)=1.0
      XARAY2(1)=XARRAY(1)
      XARAY2(2)=XARRAY(1)
      YARAY2(1)=YARRAY(1)
      YARAY2(2)=YARRAY(1)
      CALL SHADE(XARRAY,YARRAY,XARAY2,YARAY2,.05,45.0,NPTS,1,2,1)
C ANNOTATE END OF LINEAL FEATURE OR BOUNDED AREA.
C SKIP IF ZEROES INPUT FOR MAIN I.D.
  960 IF (ID(1).EQ.0) GO TO 980
      FPN=ID(1)
  970 CALL NUMBER(XARRAY(NPTS),YARRAY(NPTS),HBNDL,FPN,0.,-1)
C PRINT TOTAL HORIZONTAL & SLOPE DISTANCE.
  980 WRITE (KOUT,990) DHOR,DSLOPE
```

```
  990 FORMAT(//  1X,'TOTAL HORIZONTAL DISTANCE = ',F14.2
     1          / 1X,'TOTAL SLOPE DISTANCE = ',F14.2)
C IF TASK = BOUNDED AREAS CALC. ACREAGE. & PRINT
      IF (KURTAS.EQ.5) GO TO 1020
      DAREA=DABS(DAREA)/2.0D0
      DACRE=DAREA/43560.0D0
      WRITE (KOUT,1000) DAREA
 1000 FORMAT(1X,'GRID AREA = ',F14.1,' SQUARE FEET')
      WRITE (KOUT,1010) DACRE
 1010 FORMAT(1X,'GRID ACREAGE = ',F14.6)
C WRITE SEARCH RECORD INFO.
 1020 CALL SEARCH(NSR)
      IF (KURTAS.EQ.4) WRITE (KOUT,1030) ID(1),KURMOD
 1030 FORMAT(// 55X,'BOUNDED AREA NUMBER ',I4,' HAS BEEN PLOTTED FOR MOD
     1EL NUMBER ',I5 /55X,64('-'))
      IF (KURTAS.EQ.5) WRITE (KOUT,1040) ID(1),KURMOD
 1040 FORMAT(// 55X,'LINEAL FEATURE NUMBER ',I4,' HAS BEEN PLOTTED FOR M
     1ODEL NUMBER ',I5/55X,66('-'))
      WRITE (KOUT,670) NSR
C WRITE PEN NUMBER
      WRITE(KOUT,595) NPEN
C RETURN TO END OF TASK SECTION
      GO TO 330
C END OF PROGRAM
C---------------
C CLOSE PLOT FILES
 1050 CALL PLOT(0.,0.,999)
C WRITE MESSAGE
      WRITE (KOUT,1060)
 1060 FORMAT(///55X,'END OF PROGRAM'/55X,14('*'))
      IF (KENDI.EQ.0) WRITE (KOUT,1070) KURMOD
 1070 FORMAT( 1X,'PROGRAM ENDED TRYING TO READ ANOTHER SET OF CONTROL CA
     1RDS, WHICH COULD HAVE BEEN OMITTED.')
C PUNCH DIGITIZED DATA CARDS IF 'CARD' OPTION IS SPECIFIED
      IF (KARD.NE.KC) GO TO 1090
      REWIND KDISC
 1080 READ (KDISC,40,END=1090) DIGREC
      WRITE (KPUNCH,40) DIGREC
      GO TO 1080
 1090 CALL EXIT
      STOP
      END
```

```
      SUBROUTINE CON3D
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/CCON3D/XMOD(1500),YMOD(1500),ZMOD(1500),XGRID(20),YGRID(20)
     1,ZGRID(20),M(3,3),SCAL,TX,TY,TZ,OMEGA,PHI,KAPPA,NPT,NUMIT,NCODE,
     2 NEQ,NX,NY,NZ,KREP
      COMMON/CNORUP/OBS(5),A(4,5),X(4),KDIV
C GIVEN MODEL COORDS(XMOD,YMOD,ZMOD) AND CORRESPONDING GRID COORDS(XGRID
C ,YGRID,ZGRID) AND NUMBER OF POINTS(NPT), PERFORMS A LEAST SQUARES
C SOLUTION FOR THE 3-DIMENSIONAL CONFORMAL TRANSFORMATION PARAMETERS
C TO CONVERT MODEL COORDS TO GRID COORDINATES. RETURNS THE TRANS-
C FORMATION MATRIX 'M(3,3)',SCALE FACTOR 'SCAL', TRANSLATION PARAMETERS
C 'TX,TY,TZ', AND THE ROTATION ANGLES 'OMEGA, PHI,& KAPPA' IN RADIANS.
C REFERENCE 'ELEMENTS OF PHOTOGRAMMETRY' BY PAUL R. WOLF, PAGE 529.
C SUBROUTINES USED 'CONVER','NORSOL','AZINV','UPDATE'
C LIBRARY FUNCTIONS 'DSIN','DCOS'
C 'NUMIT' IS THE NUMBER OF ITERATIONS REQUIRED FOR SOLUTION.
C WRITTEN BY FRANK GORSHE, PORTLAND DISTRICT PHOTOGRAMMETR SECTION, AS
C PART OF PHOTOGRAMMETRIC DIGITIZING SYSTEM, JULY 1975.
C 'NCODE' TELLS WHAT HAPPENED. 0=NORMAL SOLUTION 1=UNIQUE SOL. 2=NOT
C ENOUGH VALUES FOR SOL. 3=LIMIT OF ITERATIONS REACHED, NO CONVERGENCE
C 4=DIVISION BY ZERO WHEN SOLVING NORMAL EQUATIONS.
      DIMENSION XG(20),YG(20),ZG(20)
      INTEGER XMOD,YMOD,ZMOD
      REAL*8 M,KAPPA,DUM
      INTEGER XMX(20),YMX(20),ZMX(20), XMY(20),YMY(20),ZMY(20),
     1          XMZ(20),YMZ(20),ZMZ(20)
C DEFINE FUNCTIONS FOR DOUBLE PRECISION TRIG IN CASE, SINGLE PRECISION
C IS LATER USED AND FOR SIMPLICITY OF CODING.
      SIN(DUM)=DSIN(DUM)
      COS(DUM)=DCOS(DUM)
C DEFINE MISC. VARIABLES
      NUMIT=1
      LIMIT=10
      CHECK=1.D-6
      NCODE=0
      NX1=0
      NY1=0
      NZ1=0
      NEQ=0
C SKIP IF THIS IS NOT THE FIRST ENTRANCE FORTHIS MODEL
      IF(KREP.EQ.1) GO TO 30
C INITIALIZE VALUES OF TRANSLATION PARAMETERS,OMEGA,&PHI
      OMEGA=0.0
      PHI=0.0
      KAPPA=0.0
      TX=0.0
      TY=0.0
      TZ=0.0
C DEFINE APPROXIMATE SCALE FACTOR IN CASE BETTER APPROXIMATE ONE CANNOT
C BE LATER COMPUTED
      SCAL=.10
C SOLVE FOR INITIAL VALUE OF KAPPA.
C FIND 2 POINTS WITH X&Y GRID COORDS
      NUM1=0
```

```
      NUM2=0
      DO 10 N=1,NPT
      IF(XGRID(N).EQ.0.D0.OR.YGRID(N).EQ.0.D0) GO TO 10
      IF (NUM1.NE.0) NUM2=N
      IF (NUM2.NE.0) GO TO 20
      NUM1=N
   10 CONTINUE
C SOLVE FOR APPROXIMATE KAPPA. SKIP IF 2 HORIZONTAL POINTS NOT FOUND
   20 IF (NUM2.EQ.0) GO TO 30
      XTEM1=XMOD(NUM1)
      YTEM1=YMOD(NUM1)
      XTEM2=XMOD(NUM2)
      YTEM2=YMOD(NUM2)
      CALL AZINV(YTEM1,XTEM1,YTEM2,XTEM2,AZMOD,DMOD)
      CALL AZINV(YGRID(NUM1),XGRID(NUM1),YGRID(NUM2),XGRID(NUM2),
     1                AZGRID,DGRID)
      KAPPA=AZMOD-AZGRID
C COMPUTE APPROXIMATE SCALE FACTOR.
      SCAL=DGRID/DMOD
C  LOOK FOR OBSERVED VALUES OF XGRID,YGRID,&ZGRID. SUBTRACT FROM FIRST
C  VALUE FOUND FOR EACH OF THE 3 GROUPS TO ELIMINATE TRANSLATION
C  PARAMETERS. THESE SUBTRACTED VALUES WILL BE USED TO FORM THE CONDIT-
C  ION EQUATIONS. SEE PAGE 535 OF REFERENCE FOR DETAILED EXPLAINATION.
C
C FIND THE POINT NUMBERS FOR THE FIRST NON-ZERO VALUES OF X,Y,& ZGRID
   30 DO 40 N=1,NPT
      IF (XGRID(N).NE.0.D0.AND.NX1.EQ.0) NX1=N
      IF (YGRID(N).NE.0.D0.AND.NY1.EQ.0) NY1=N
      IF (ZGRID(N).NE.0.D0.AND.NZ1.EQ.0) NZ1=N
   40 CONTINUE
C CHECK FOR NO VALUES OR VALUE=NPT. RETURN WITH PROPER CODE IF SO.
      IF (NX1.EQ.0.OR.NY1.EQ.0.OR.NZ1.EQ.0) NCODE=2
      IF (NX1.EQ.NPT.OR.NY1.EQ.NPT.OR.NZ1.EQ.NPT) NCODE=2
      IF (NCODE.EQ.2) GO TO 200
C SOLVE FOR NUMBER OF'X'CONDITIONS(NX) AND THE SUBTRACTED COORDINATES.
      NX=0
      NSTART=NX1+1
      DO 50 N=NSTART,NPT
      IF (XGRID(N).EQ.0.D0) GO TO 50
      NX=NX+1
      XG(NX)=XGRID(NX1)-XGRID(N)
      XMX(NX)=XMOD(NX1)-XMOD(N)
      YMX(NX)=YMOD(NX1)-YMOD(N)
      ZMX(NX)=ZMOD(NX1)-ZMOD(N)
   50 CONTINUE
C SOLVE FOR THE'Y'SUBTRACTED CONDITIONS.
      NY=0
      NSTART=NY1+1
      DO 60 N=NSTART,NPT
      IF (YGRID(N).EQ.0.D0) GO TO 60
      NY=NY+1
      YG(NY)=YGRID(NY1)-YGRID(N)
      XMY(NY)=XMOD(NY1)-XMOD(N)
      YMY(NY)=YMOD(NY1)-YMOD(N)
```

```
      ZMY(NY)=ZMOD(NY1)-ZMOD(N)
   60 CONTINUE
C SOLVE FOR THE'Z' SUBTRACTED CONDITIONS.
      NZ=0
      NSTART=NZ1+1
      DO 70 N=NSTART,NPT
      IF (ZGRID(N).EQ.0.D0) GO TO 70
      NZ=NZ+1
      ZG(NZ)=ZGRID(NZ1)-ZGRID(N)
      XMZ(NZ)=XMOD(NZ1)-XMOD(N)
      YMZ(NZ)=YMOD(NZ1)-YMOD(N)
      ZMZ(NZ)=ZMOD(NZ1)-ZMOD(N)
   70 CONTINUE
C CHECK FOR ADEQUATE NUMBER OF CONDITIONS FOR SOLUTION. RETURN IF NOT.
      IF (NX.LT.1) NCODE=2
      IF (NY.LT.1) NCODE=2
      IF (NZ.LT.2) NCODE=2
      IF (NCODE.EQ.2) GO TO 200
C CALCULATE NUMBER OF CONDITION EQUATIONS. SHOULD BE 4 OR MORE.
C CHECK FOR UNIQUE SOLUTION. SET CODE IF SO AND CONTINUE.
      NEQ=NX+NY+NZ
      IF (NEQ.EQ.4) NCODE=1
C USING CURRENT VALUES OF OMEGA,PHI,&KAPPA, FORM ROTATION MATRIX  M(3,3)
C USING EQUATIONS ON PAGE 533 OF REFERENCE.
   80 M(1,1)=COS(PHI)*COS(KAPPA)
      M(1,2)=SIN(OMEGA)*SIN(PHI)*COS(KAPPA)+COS(OMEGA)*SIN(KAPPA)
      M(1,3)=-COS(OMEGA)*SIN(PHI)*COS(KAPPA)+SIN(OMEGA)*SIN(KAPPA)
      M(2,1)=-COS(PHI)*SIN(KAPPA)
      M(2,2)=-SIN(OMEGA)*SIN(PHI)*SIN(KAPPA)+COS(OMEGA)*COS(KAPPA)
      M(2,3)=COS(OMEGA)*SIN(PHI)*SIN(KAPPA)+SIN(OMEGA)*COS(KAPPA)
      M(3,1)=SIN(PHI)
      M(3,2)=-SIN(OMEGA)*COS(PHI)
      M(3,3)=COS(OMEGA)*COS(PHI)
C INITIALIZE NORMAL EQUATION MATRIX 'A' TO ZEROES.
      DO 100 N=1,5
      DO 90  K=1,4
   90 A(K,N)=0.D0
  100 CONTINUE
C
C FORM OBSERVATION EQUATIONS & UPDATE NORMAL EQUATIONS FOR X,Y,&Z GROUPS
C EQUATIONS ARE FROM PAGE 537 OF REFERENCE
C
C FORM FOR X-GROUP
      DO 110 N=1,NX
      OBS(1)=M(1,1)*XMX(N)+M(2,1)*YMX(N)+M(3,1)*ZMX(N)
      OBS(2)=0.0
      OBS(3)=((-SIN(PHI)*COS(KAPPA))*XMX(N)+SIN(PHI)*SIN(KAPPA)*YMX(N)+
     1 COS(PHI)*ZMX(N))*SCAL
      OBS(4)=(M(2,1)*XMX(N)-M(1,1)*YMX(N))*SCAL
C FORM CONSTANT(PAGE 536(B-32))
      CALL CONVER(XMX(N),YMX(N),ZMX(N),XTEMP,YTEMP,ZTEMP)
      OBS(5)=XTEMP-XG(N)
C UPDATE NORMAL EQUATIONS
      CALL UPDATE
```

```
  110 CONTINUE
C
C FORM Y-GROUP
      DO 120 N=1,NY
      OBS(1)=M(1,2)*XMY(N)+M(2,2)*YMY(N)+M(3,2)*ZMY(N)
      OBS(2)=(-M(1,3)*XMY(N)-M(2,3)*YMY(N)-M(3,3)*ZMY(N))*SCAL
      OBS(3)=(SIN(OMEGA)*COS(PHI)*COS(KAPPA)*XMY(N)-SIN(OMEGA)*COS(PHI)*
     1 SIN(KAPPA)*YMY(N)+SIN(OMEGA)*SIN(PHI)*ZMY(N))*SCAL
      OBS(4)=(M(2,2)*XMY(N)-M(1,2)*YMY(N))*SCAL
C FORM CONSTANT
      CALL CONVER(XMY(N),YMY(N),ZMY(N),XTEMP,YTEMP,ZTEMP)
      OBS(5)=YTEMP-YG(N)
C UPDATE NORMAL EQS.
      CALL UPDATE
  120 CONTINUE
C
C FORM Z-GROUP
      DO 130 N=1,NZ
      OBS(1)=M(1,3)*XMZ(N)+M(2,3)*YMZ(N)+M(3,3)*ZMZ(N)
      OBS(2)=(M(1,2)*XMZ(N)+M(2,2)*YMZ(N)+M(3,2)*ZMZ(N))*SCAL
      OBS(3)=(-COS(OMEGA)*COS(PHI)*COS(KAPPA)*XMZ(N)+COS(OMEGA)*COS(PHI)
     1 *SIN(KAPPA)*YMZ(N)-COS(OMEGA)*SIN(PHI)*ZMZ(N))*SCAL
      OBS(4)=(M(2,3)*XMZ(N)-M(1,3)*YMZ(N))*SCAL
C FORM CONSTANT
      CALL CONVER(XMZ(N),YMZ(N),ZMZ(N),XTEMP,YTEMP,ZTEMP)
      OBS(5)=ZTEMP-ZG(N)
C UPDATE NORMAL EQS.
      CALL UPDATE
  130 CONTINUE
C
C NORMAL EQUATIONS ARE COMPLETE. SOLVE THEM FOR CORRECTIONS TO THE
C CURRENT VALUES OF THE PARAMETERS. IF CORRECTIONS ARE STILL
C OF SIGNIFICANT SIZE, CORRECT PARAMETERS AND RETURN FOR ANOTHER
C ITERATION
C
C SOLVE NORMAL EQUATIONS
      CALL NORSOL
C CHECK FOR DIVISION BY ZERO
      IF (KDIV.EQ.1) NCODE=4
      IF (KDIV.EQ.1) GO TO 200
C CHECK SIZE OF CORRECTIONS
      DO 140 N=1,4
      IF (DABS(X(N)).GT.CHECK) GO TO 150
  140 CONTINUE
      GO TO 160
C CHECK FOR REACHING LIMIT OF ITERATIONS.
  150 IF (NUMIT.GE.LIMIT) NCODE=3
      IF (NUMIT.GE.LIMIT) GO TO 160
C CORRECT PARAMETERS & RETURN FOR ANOTHER ITERATION.
      SCAL=SCAL+X(1)
      OMEGA=OMEGA+X(2)
      PHI=PHI+X(3)
      KAPPA=KAPPA+X(4)
      NUMIT=NUMIT+1
```

```
      GO TO 80
C
C CONVERGENCE HAS OCCURRED. COMPUTE TRANSLATION PARAMETERS
C USING SUBSTITUTION AND AVERAGING.
C
C CALCULATE 'X' TRANSLATION
  160 SUMT=0.
      DO 170 N=1,NPT
      IF (XGRID(N).EQ.0.D0) GO TO 170
      CALL CONVER(XMOD(N),YMOD(N),ZMOD(N),XTEMP,YTEMP,ZTEMP)
      TRAN=XGRID(N)-XTEMP
      SUMT=SUMT+TRAN
  170 CONTINUE
      TX=SUMT/(NX+1)
C COMPUTE 'Y' TRANSLATION
      SUMT=0.
      DO 180 N=1,NPT
      IF (YGRID(N).EQ.0.D0) GO TO 180
      CALL CONVER(XMOD(N),YMOD(N),ZMOD(N),XTEMP,YTEMP,ZTEMP)
      TRAN=YGRID(N)-YTEMP
      SUMT=SUMT+TRAN
  180 CONTINUE
      TY=SUMT/(NY+1)
C COMPUTE 'Z' TRANSLATION
      SUMT=0.0
      DO 190 N=1,NPT
      IF (ZGRID(N).EQ.0.D0) GO TO 190
      CALL CONVER(XMOD(N),YMOD(N),ZMOD(N),XTEMP,YTEMP,ZTEMP)
      TRAN=ZGRID(N)-ZTEMP
      SUMT=SUMT+TRAN
  190 CONTINUE
      TZ=SUMT/(NZ+1)
C
C END OF SUBROUTINE
C
  200 RETURN
      END
```

```
      SUBROUTINE NORSOL
      IMPLICIT REAL*8(A-H,O-Z)
C USING GAUSS-DOOLITTLE METHOD SOLVES NORMAL EQUATIONS 'A(4,5)' FOR
C UNKNOWNS 'X(4)'. DIVISION BY ZERO RETURNS ERROR CODE 'KDIV=1'
C REFERENCE - PAGE 73 OF 'LEAST SQUARES IN GEODESY & PHOTOGRAMMETRY'
C BY HIRVONEN.
      COMMON/CNORUP/OBS(5),A(4,5),X(4),KDIV
      DIMENSION T(4,5),R(4,5)
      KDIV=0
C FORM REDUCED & END EQUATIONS('R'&'T') FOR 1ST ROW.
      DO 10 J=1,5
      R(1,J)=A(1,J)
      IF (R(1,1).EQ.0.D0) GO TO 80
   10 T(1,J)=-R(1,J)/R(1,1)
C DO THE SAME FOR THE REMAINING ROWS.
      DO 50 I=2,4
      DO 30 J=1,5
C FORM SUM OF 'TXR'
      SUM=0.0
      LAST=I-1
      DO 20 N=1,LAST
   20 SUM=SUM+T(N,I)*R(N,J)
C DEFINE 'R' TERMS FOR THIS ROW.
   30 R(I,J)=A(I,J)+SUM
C DEFINE 'T' TERMS FOR THIS ROW. FIRST MAKE DIVISION CHECK.
      IF (R(I,I).EQ.0.D0) GO TO 80
      DO 40 NCOL=1,5
   40 T(I,NCOL)=-R(I,NCOL)/R(I,I)
   50 CONTINUE
C SOLVE FOR UNKNOWNS USING BACK SOLUTION.
      X(4)=T(4,5)
      DO 70 N=1,3
      I=4-N
      SUM=0.0
      J1=I+1
      DO 60 J=J1,4
   60 SUM=SUM+T(I,J)*X(J)
      X(I)=T(I,5)+SUM
   70 CONTINUE
      GO TO 90
C SET DIVISION BY ZERO CODE.
   80 KDIV=1
   90 RETURN
      END
```

```
      SUBROUTINE UPDATE
C GIVEN TERMS OF OBSERVATION EQUATION(INCLUDING CONSTANT) 'OBS(5)'
C UPDATES NORMAL EQUATIONS MATRIX 'A(4,5)'
      COMMON/CNORUP/OBS(5),A(4,5),X(4),KDIV
      REAL*8 OBS,A,X
C UPDATE PARAMETER PORTION OF NORMAL EQS.  A(1,1) THRU A(4,4)
      DO 20 N=1,4
      DO 10 K=1,4
   10 A(N,K)=A(N,K)+OBS(N)*OBS(K)
   20 CONTINUE
C UPDATE CONSTANT PORTION OF NORMAL EQS. A(1,5) THRU A(4,5)
      DO 30 N=1,4
   30 A(N,5)=A(N,5)+OBS(N)*OBS(5)
      RETURN
      END
```

```
      SUBROUTINE CONVER(XM,YM,ZM,XG,YG,ZG)
C     CONVERTS FROM MODEL COORDINATES TO GRID COORDS USING 3-DIMENSIONAL
C     CONFORMAL TRANSFORMATION PARAMETERS'M(3,3),SCALE,TX,TY,TZ'
      COMMON/CCON3D/XMOD(1500),YMOD(1500),ZMOD(1500),XGRID(20),YGRID(20)
     1,ZGRID(20),M(3,3),SCAL,TX,TY,TZ,OMEGA,PHI,KAPPA,NPI,NUMIT,NCODE,
     2 NEQ,NX,NY,NZ,KREP
      INTEGER XM,YM,ZM,XMOD,YMOD,ZMOD
      REAL*8 XG,YG,ZG,XGRID,YGRID,ZGRID,M,SCAL,TX,TY,TZ,OMEGA,PHI,KAPPA
      XG=SCAL*(M(1,1)*XM+M(2,1)*YM+M(3,1)*ZM)+TX
      YG=SCAL*(M(1,2)*XM+M(2,2)*YM+M(3,2)*ZM)+TY
      ZG=SCAL*(M(1,3)*XM+M(2,3)*YM+M(3,3)*ZM)+TZ
      RETURN
      END
```

```
      SUBROUTINE AZINV(N1,E1,N2,E2,AZM,DIST)
C GIVEN GRID COORDINATES, RETURNS CLOCK-WISE AZMUTH REFERENCED FROM
C NORTH AND DISTANCE. ALL ARGUMENTS ARE DOUBLE PRECISION. AZM IN RADIANS
      REAL*8 N1,E1,N2,E2,AZM,DIST,LAT,DEP
C CALCULATE DISTANCE.
      LAT=N2-N1
      DEP=E2-E1
      DIST=DSQRT(LAT**2+DEP**2)
      IF (DIST.EQ.0.D0) GO TO 10
C CALCULATE AZMUTH FOR FIRST TWO QUADRANTS
      AZM=DARCOS(LAT/DIST)
C CHANGE AZM FOR QUADRANTS WITH NEGATIVE DEPARTURES.
      IF (DEP.LT.0.D0)AZM=6.283185308D0-AZM
      GO TO 30
C WRITE DIAGNOSTIC FOR DIST=0
   10 WRITE (6,20)
   20 FORMAT(//10X,'*DIAGNOSTIC* INVALID INVERSE. DISTANCE BETWEEN COORD
     1INATES EQUALS ZERO.')
   30 RETURN
      END
```

```
      SUBROUTINE MANPLT(NPT,NSCALE,GRIDOR,NTITLE,METRIC)
C MODIFICATION OF
C PHOTOGRAMMETRIC MANUSCRIPT PROGRAM. PLOTS CONTROL POINTS AND GRID
C TICKS AT SPECIFIED ORIENTATION. AUTHOR, FRANK GORSHE, PORTLAND
C DISTRICT CORPS OF ENGINEERS, PHOTOGRAMMETRY SECTION, JANUARY 1975.
      COMMON/CCON3D/XDUM(1500),YDUM(1500),ZDUM(1500),ECORD(20),NCORD(20)
     1,ELEV(20),FILL(148)
      COMMON/CROTRN/XORIG,YORIG,ENSCAL,THETA
      COMMON/CMAXMN/XMAX,YMAX,XMIN,YMIN
      DIMENSION NTITLE(20)
      REAL*8 NCORD,ECORD,XORIG,YORIG,ENSCAL,XD,YD,AZM,DIST,THETA,ELEV
      REAL*8 LGRID
C DEFINE CONSTANTS FOR PLOT CHARACTERS
      HTICL=.06
      HTIC=.5
      HTITLE=.10
      HCONL=.08
      HCON=.10
C DEFINE I/O CONSTANTS
      KOUT=6
C DEFINE MISC. CONSTANTS.
      NMAN=0
      DUM=0.0
C DEFINE PLOTTER LIMITS IN INCHES
      XLIM=74.0
      YLIM=51.0
C DEFINE PLOT CHARACTERS FOR CONTROL POINTS
      KVERT=1
      KHOR= 2
C DEFINE GRID TICK LENGTH
      LGRID=5.0D0
C REDEFINE FOR NON-ENGINEERS SCALE
      IF(MOD(NSCALE,12).NE.0) LGRID=6.0D0
C REDEFINE FOR 15 MINUTE QUAD SCALE
      IF(NSCALE.EQ.62500) LGRID=3.84D0
C BEGIN PROGRAM
C DEFINE INITIAL PARAMETERS OF COORD. TRANS.
   10 XORIG=0.0
      YORIG=0.0
      ENSCAL=NSCALE/12.0D0
      THETA=-GRIDOR/57.29577951D0
C IF NEITHER CORNER WAS REFERENCED CALC. TRANS. PARAMETERS.
      CALL ERASMM
C FIND MAX & MIN VALUES OF CONTROL POINTS
      DO 20  N=1,NPT
      CALL ROTRAN(ECORD(N),NCORD(N),XTEST,YTEST,1)
      CALL MAXMIN(XTEST,YTEST)
   20 CONTINUE
C CALCULATE XMAN & YMAN. CHANGE SCALE IF TOO LARGE.
      XMAN=XMAX-XMIN+4.0
      YMAN=YMAX-YMIN+4.0
      IF (XMAN.LT.XLIM.AND.YMAN.LT.YLIM) GO TO 40
      NSCALE=NSCALE*2
      WRITE (KOUT,30) NSCALE
```

```
 30 FORMAT(//11X,'REQUESTED SCALE TOO BIG. NEW SCALE 1/',I6)
    GO TO 10
C CALCULATE TRANSLATION PARAMETERS.
C ALLOW FOR 2 INCH MARGIN WHEN SOLVING FOR PLOT ORIGIN.
 40 XMIN=XMIN-2.0
    YMIN=YMIN-2.0
    CALL ROTRAN(XORIG,YORIG,XMIN,YMIN,2)
C WRITE MESSAGE FOR PLOT DIMENSIONS
 50 XMANT=XMAN+5.0
    WRITE (KOUT,60) XMANT,YMAN
 60 FORMAT(///30X,'MANUSCRIPT DIMENSIONS      XPLOTTER = ',F4.1,' INCHE
   1S    YPLOTTER = ',F4.1,' INCHES'/30X,75('-'))
C REORIGIN AND WRITE OUT PLOT INFORMATION.
    CALL NWDRAW(XMANT,YMAN)
C PLOT GRID TICKS.
 70 CALL GRDTIC(0.,0.,XMAN,YMAN,GRIDOR,LGRID,HTIC,1)
    CALL SEARCH(NSR)
    WRITE (KOUT,80)
 80 FORMAT(//53X,'GRID TICKS HAVE BEEN PLOTTED'/53X,28('-'))
    WRITE (KOUT,90) NSR
 90 FORMAT(55X,'SEARCH RECORD NUMBER',I4)
C LABEL PERIMETER OF MANUSCRIPT WITH GRID TICKS.
    CALL PLOT(0.,0.,-3)
    WIDTH=LGRID
    CALL GRDTIC(0.,0.,WIDTH,YMAN,GRIDOR,LGRID,HTICL,2)
    CALL GRDTIC(WIDTH,0.,XMAN-2*WIDTH,WIDTH,GRIDOR,LGRID,HTICL,2)
    CALL GRDTIC(XMAN-WIDTH,0.,WIDTH,YMAN,GRIDOR,LGRID,HTICL,2)
    CALL GRDTIC(WIDTH,YMAN-WIDTH,XMAN-2*WIDTH,WIDTH,GRIDOR,LGRID,HTICL
   1,2)
    CALL SEARCH(NSR)
    WRITE (KOUT,100)
100 FORMAT(//53X,'GRID TICKS HAVE BEEN LABELED'/53X,28('-'))
    WRITE (KOUT,90) NSR
C PLOT CONTROL POINTS. OMIT IF NOT WITHIN PLOT RANGE.
    CALL PLOT(0.,0.,-3)
    DO 120 N=1,NPT
    CALL ROTRAN(ECORD(N),NCORD(N),XPLOT,YPLOT,1)
C DEFINE PLOT CODE DEPENDING ON TYPE OF CONTROL POINT OR VALUE OF NSYM
110 KP=KHOR
    IF (ELEV(N).NE.0.D0) KP=KVERT
C PLOT THE CONTROL POINT
    CALL SYMBOL(XPLOT,YPLOT,HCON,KP,0.,-1)
C IF SYMBOL IS 0,1,OR2 REPLOT WITH + SYMBOL TO BETTER DEFINE CENTER.
    H2=.4*HCON
    IF (KP.LE.2.OR.KP.EQ.5) CALL SYMBOL (XPLOT,YPLOT,H2,3,0.,-1)
C PLOT CONTROL POINT SEQUENCE NO.
    CALL SYMBOL(999.,999.,HCONL,'CP '  ,0.,3)
    FPN=N
    CALL NUMBER(999.,999.,HCONL,FPN,0.,-1)
120 CONTINUE
C WRITE MESSAGE
    CALL SEARCH(NSR)
    WRITE (KOUT,130)
130 FORMAT(//53X,'CONTROL POINTS HAVE BEEN PLOTTED'/53X,32('-'))
```

```
      WRITE (KOUT,90) NSR
C PLOT TITLE.
      CALL PLOT(0.,0.,-3)
      XPLOT=XMAN+.5
      YPLOT=3.2*HTITLE
      CALL SYMBOL(XPLOT,YPLOT,HTITLE,NTITLE(1),0.,40)
      YPLOT=1.6*HTITLE
      CALL SYMBOL(XPLOT,YPLOT,HTITLE,NTITLE(11),0.,40)
C PLOT PROPORTIONAL SCALE.
      YPLOT=0.
      RSCALE=NSCALE
      CALL SYMBOL(XPLOT,YPLOT,HTITLE,'SCALE 1/',0.,8)
      CALL NUMBER(999.,999.,HTITLE,RSCALE,0.,-1)
C PLOT NORTH ARROW.
      XPLOT=XMAN+2.5
      YPLOT=5.0
      CALL NORTH(XPLOT,YPLOT,2.0,GRIDOR)
C WRITE MESSAGE
      CALL SEARCH(NSR)
      WRITE (KOUT,140)
  140 FORMAT(//53X,'TITLE, SCALE, AND NORTH ARROW HAVE BEEN PLOTTED'/
     1 53X,47('-'))
      WRITE (KOUT,90) NSR
      RETURN
      END
```

```
      SUBROUTINE GRDTIC(XCORN,YCORN,XCOV,YCOV,GRIDOR,LGRID,HITE,KODE)
C FILLS IN WINDOW ON PLOTTER WITH GRID TICKS ORIENTED 'GRIDOR' DEGREES
C FROM PLOTTER +Y AXIS, SPACED'LGRID' INCHES, AND OF HIGHT 'HITE'.
C WINDOW IS DEFINED BY LEFT LOWER CORNER PLOT COORDS OF 'XCORN,YCORN'
C AND DIMENSIONS 'XCOV' BY 'YCOV'.
C THIS SUBROUTINE MUST BE USED IN CONJUNCTION WITH'SUBROUTINE ROTRAN'.
      COMMON/CRDTRN/XORIG,YORIG,ENSCAL,THETA
C IF KODE=2 GRID TICKS ARE LABELED BUT NOT PLOTTED WITH NUMBERS OF
C DIMENSION 'HITE'.
      REAL*8 XORIG,YORIG,GX1,GY1,GX2,GY2,GX3,GY3,GX4,GY4,GDIST,ENSCAL,
     1 GDIST,GXREF,GYREF,GYTEM,GXTEM,GYD,GXD,LGRID
C SOLVE FOR PLOT COORDS OF REMAINING 3 CORNERS.
      X1=XCORN+XCOV
      Y1=YCORN
      X2=X1
      Y2=YCORN+YCOV
      X3=XCORN
      Y3=Y2
C CONVERT TO GROUND COORDS.
      CALL ROTRAN(GX1,GY1,X1,Y1,2)
      CALL ROTRAN(GX2,GY2,X2,Y2,2)
      CALL ROTRAN(GX3,GY3,X3,Y3,2)
      CALL ROTRAN(GX4,GY4,XCORN,YCORN,2)
C SOLVE FOR MAX & MIN VALUES OF GROUND COORDS.
      GXMAX=DMAX1(GX1,GX2,GX3,GX4)
      GXMIN=DMIN1(GX1,GX2,GX3,GX4)
      GYMAX=DMAX1(GY1,GY2,GY3,GY4)
      GYMIN=DMIN1(GY1,GY2,GY3,GY4)
C SOLVE FOR MIN. EVEN VALUES OF GROUND COORDS.
      GDIST=LGRID*ENSCAL
      LGDIST=GDIST+.0001
      NTEMP=GXMIN/GDIST
      GXREF=NTEMP*LGDIST
      NTEMP=GYMIN/GDIST
      GYREF=NTEMP*LGDIST
C SOLVE FOR NUMBER OF TICKS IN NORTH AND EAST DIRECTION.
      NTKSN=(GYMAX-GYMIN)/GDIST+1
      NTKSE=(GXMAX-GXMIN)/GDIST+1
C PLOT AT LEAST 4 GRID TICKS ON SMALL PLOTS.
      IF(NTKSN.LT.2) NTKSN=2
      IF(NTKSE.LT.2) NTKSE=2
C PLOT GRID-TICKS. ELIMINATE THOSE WHICH DO NOT FALL WITHIN WINDOW.
C IF KODE=2,   TICKS ARE LABELED BUT NOT PLOTTED.
      DO 30 KN=1,NTKSN
      DO 20 KE=1,NTKSE
      GXTEM=GXREF+KE*LGDIST
      GYTEM=GYREF+KN*LGDIST
      CALL ROTRAN(GXTEM,GYTEM,XPLOT,YPLOT,1)
      IF(NTKSN.EQ.2.AND.NTKSE.EQ.2.AND.KODE.EQ.1) GO TO 5
      IF (XPLOT.GT.X2.OR.XPLOT.LT.XCORN.OR.YPLOT.GT.Y3.OR.YPLOT.LT.YCORN
     1) GO TO 20
    5 IF (KODE.EQ.2) GO TO 10
      CALL SYMBOL(XPLOT,YPLOT,HITE,3,GRIDOR,-1)
      GO TO 20
```

```
C LABEL GRID-TICK POSITION WITH COORDINATE VALUES
   10 CONTINUE
C LABEL NORTHING. SHIFT .1 INCHES TO THE EAST.
      GXD=GXTEM+.1*ENSCAL
      GYD=GYTEM+.02*ENSCAL
      CALL ROTRAN(GXD,GYD,XPLOT,YPLOT,1)
      FPN=GYTEM
      CALL NUMBER(XPLOT,YPLOT,HITE,FPN,GRIDOR,-1)
      CALL SYMBOL(999.,999.,HITE,'N',GRIDOR,1)
C LABEL EASTING. SHIFT .1 INCHES TO THE SOUTH.
      GXD=GXTEM+.02*ENSCAL
      GYD=GYTEM-.1*ENSCAL
      CALL ROTRAN(GXD,GYD,XPLOT,YPLOT,1)
      ANG=GRIDOR-90.0
      FPN=GXTEM
      CALL NUMBER(XPLOT,YPLOT,HITE,FPN,ANG,-1)
      CALL SYMBOL(999.,999.,HITE,'E',ANG,1)
   20 CONTINUE
   30 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MAXMIN(X,Y)
C MAINTAINS UP TO DATE THE VARIABLES IN COMMON 'XMAX,YMAX,XMIN,YMIN'
      COMMON/CMAXMN/XMAX,YMAX,XMIN,YMIN
      XMAX=AMAX1(X,XMAX)
      YMAX=AMAX1(Y,YMAX)
      XMIN=AMIN1(X,XMIN)
      YMIN=AMIN1(Y,YMIN)
      RETURN
      END
```

```
      SUBROUTINE ERASMM
C SETS VALUES OF MAX-MIN VARIABLES TO EXTREME VALUES TO START NEW TALLY.
      COMMON/CMAXMN/XMAX,YMAX,XMIN,YMIN
      XMAX=-1.0E20
      YMAX=-1.0E20
      XMIN=1.0E20
      YMIN=1.0E20
      RETURN
      END
```

```
      SUBROUTINE ROTRAN(X1,Y1,X2,Y2,KODE)
C SCALES,ROTATES,AND TRANSLATES FROM ONE COORDINATE SYSTEM TO ANOTHER.
C IF KODE=1, FROM OLD TO NEW.  IF KODE=2 FROM NEW TO OLD
      COMMON/CROTRN/XORIG,YORIG,ENSCAL,ANGLE
      REAL*8 X1,Y1,XORIG,YORIG,YTEMPD,XTEMPD,ENSCAL
      REAL*8 XTEMP,YTEMP,THETA,ANGLE,DUM,SIN,COS
      SIN(DUM)=DSIN(DUM)
      COS(DUM)=DCOS(DUM)
C CHECK KODE TO SEE WHAT DIRECTION CONVERSION IS IN.
C GO TO APPROPRIATE PART OF PROGRM.
      IF (KODE.EQ.2) GO TO 10
C CONVERSION IS FROM OLD TO NEW SYSTEM.
C TRANSLATE COORDS TO PARALLEL SYSTEM WITH SAME ORIGIN AS NEW SYSTEM
C AND REDUCE TO THE SAME SCALE.
      THETA=ANGLE
      XTEMP=(X1-XORIG)/ENSCAL
      YTEMP=(Y1-YORIG)/ENSCAL
C ROTATE TO NEW COORD SYSTEM.
      X2=XTEMP*COS(THETA)+YTEMP*SIN(THETA)
      Y2=YTEMP*COS(THETA)-XTEMP*SIN(THETA)
      GO TO 20
C CONVERSION IS FROM NEW TO OLD
   10 CONTINUE
C ROTATE PARALLEL TO OLD SYSTEM
      THETA=-ANGLE
      XTEMP=X2*COS(THETA)+Y2*SIN(THETA)
      YTEMP=Y2*COS(THETA)-X2*SIN(THETA)
C CHANGE SCALE TO SAME AS OLD SYSTEM
      XTEMPD=XTEMP*ENSCAL
      YTEMPD=YTEMP*ENSCAL
C TRANSLATE TO SAME ORIGIN AS OLD SYSTEM.
      X1=XTEMPD+XORIG
      Y1=YTEMPD+YORIG
C END OF SUBROUTINE.
   20 RETURN
      END
```

```
      FUNCTION LIMP(XPLOT,YPLOT)
C TESTS TO SEE IF'XPLOT & YPLOT' ARE WITHIN PERMISSABLE PLOTTER
C LIMITS'XMAN&YMAN', RETURNS '0' IF O.K., '1' IF NOT WITHIN,
      COMMON/CLIMP/XMAN,YMAN
      LIMP=0
      IF (XPLOT.LT.0.0.OR.XPLOT.GT.XMAN.OR.YPLOT.LT.0.0.OR.YPLOT.GT.YMAN
     1) LIMP=1
      RETURN
      END
```

```
      SUBROUTINE MULTOB(XMOD,YMOD,ZMOD,NPTS,NOBS)
C AVERAGES READINGS OF DIGITIZED XYZ MODEL COORDINATES.
C 'NOBS'=NUMBER OF OBSERVATIONS
      COMMON/MULT/KST,ID,IDS
      INTEGER*2 KST(1500),ID(1500),IDS(1500)
      INTEGER XMOD(1),YMOD(1),ZMOD(1)
      REAL*8 SUMX,SUMY,SUMZ
      IF(NOBS.LE.1) GO TO 400
      DO 368 N=1,NPTS,NOBS
      SUMX=0.
      SUMY=0.
      SUMZ=0.
      DO 366 K=1,NOBS
      SUMX=XMOD(N+K-1) +SUMX
      SUMY=YMOD(N+K-1) +SUMY
  366 SUMZ=ZMOD(N+K-1) +SUMZ
      NEW=(N+NOBS-1)/NOBS
      KST(NEW)=KST(N)
      ID(NEW)=ID(N)
      IDS(NEW)=IDS(N)
      XMOD(NEW)=SUMX/NOBS
      YMOD(NEW)=SUMY/NOBS
  368 ZMOD(NEW)=SUMZ/NOBS
C CHECK FOR CORRECT MULTIPLE OF POINTS & CALC NEW # OF POINTS
      IF(MOD(NPTS,NOBS).NE.0) WRITE(    6,369)
  369 FORMAT(/5X,'*DIAGNOSTIC* NUMBER OF CONTROL POINTS DIGITZED IS NOT
     1AN EVEN MULTIPLE OF NUMBER OF OBSERVATIONS.')
      NPTS=NPTS/NOBS
  400 RETURN
      END
```